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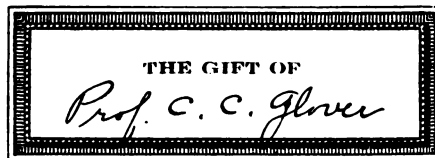
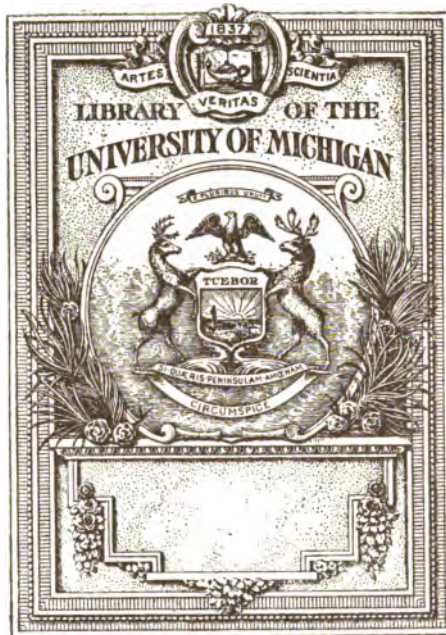
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ARITHMETIC OF PHARMACY

BY

A. B. STEVENS, PH.D., PH.C.

*School of Pharmacy, University
of Michigan*

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REPRINTED FROM MERCK'S REPORT

THIRD EDITION

NEW YORK
MERCK & CO.

1913

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Prof. C. C. Glover
7
7-29-1924

PREFACE

This work is intended to cover all of the calculations required by the practical pharmacist.

While the work will be useful to those in actual practice, its greatest value will be to students of pharmacy, whether in college or in the store.

The use of higher mathematical terms has been carefully avoided, and the analyses made as simple as possible that they may better serve the needs of those who have been deprived of a liberal education. For the same reason, some subjects have been treated in a manner that may seem unnecessarily simple, but these may be omitted by the more advanced students.

The atomic and molecular weights used in this book are obtained from the table of International Atomic Weights published by the Journal of the American Chemical Society, Vol. XXV, p. 1, 1903. $H = 1$.

The specific gravity of substance is usually given when necessary for calculation of problems. Otherwise, the student is referred to the Pharmacopœia, 8th Dec. Revision, upon which all the problems are based.

I am indebted to W. H. Blome, M.S., and to Don. S. Stevens, A.B., for assistance in verifying results.

PREFACE TO THE SECOND EDITION

A few corrections and changes have been made in the present edition. The author has also had under consideration the advisability of omitting rules, but after consultation with eminent teachers of mathematics has decided to retain them for the present. The author has always looked upon a rule as a concise statement of the method by which a problem may be solved, rather than a fixed rule to be committed to memory. The student should understand each step, and it was with this in view that the first part of alligation was given instead of depending upon the arbitrary, second rule given on page 34. This would be unnecessary if alligation was taught in all public schools, but it is a fact that many graduates of high schools have never studied this subject. Others, capable in mathematics, become confused when applying proportion to molecular quantities. It is for this reason that the author departs from his usual custom and asks students to apply the rule given at the bottom of page 44. However, this does not prevent them from thoroughly understanding the principles of proportion.

In a work comprising so many calculations it is not strange that a few errors should appear. These have been corrected where observed. Should others be detected, the author will deem it a favor if the page and problem are kindly pointed out to him. The calculations of many of the problems require a number of decimals, and the extent to which these are carried may account for slight differences in the results. A. B. S.

October, 1907.



PREFACE TO THE THIRD EDITION

The atomic weights used in the VIII Revision of the United States Pharmacopœia are based on hydrogen = 1 as the unit. However, most teachers of chemistry were at the time of the revision using atomic weights based on oxygen = 16. As this work was intended primarily for pharmacists it seemed advisable to use the hydrogen standard for the earlier editions, but the time has now come when it is necessary to change to the standard of oxygen = 16. Therefore, all of that part of the 3rd edition in which atomic or molecular weights are used has been changed to conform to the 1912 table of international atomic weights, which is the standard used for all pharmacopœias recently issued, and will be the standard for the U. S. P. IX.

In deference to the wishes of a few of the teachers who are using this work, the answers to about half of the problems have been omitted. This gives the teacher a better opportunity to test the ability of the students to work independently.

Two sections of miscellaneous problems have been added. The first section is given to test the ability of the student to solve problems independently of any directions. Those of the second section are intended to enable the student to become familiar with the pharmacopœial tables. Most of the problems may be solved independently of the tables, but in every case the student should solve the problem, or find the answer, by means of the tables in the latest edition of the Pharmacopœia.

July, 1913.

A. B. S.

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Length *Volume* *Weight*
1000 *1000* *1000*

ARITHMETIC OF PHARMACY

TABLES—WEIGHTS AND MEASURES

METRIC SYSTEM

LINEAR MEASURE

1 Meter, M. = 10 decimeters, dm. = 100 centimeters, cm. = 1000 millimeters, mm. The decimeter, centimeter and millimeter are frequently expressed in fractions of a meter, thus:—
1 dm. = 0.1 M.; 1 cm. = 0.01 M.; 1 mm. = 0.001 M.

MEASURES OF CAPACITY

1 Liter, L. = 10 deciliters, dl. = 100 centiliters, cl. = 1000 milliliters, ml. The terms deciliter, centiliter and milliliter are rarely used; but the term cubic centimeter, Cc., is employed in place of the milliliter. 1 dl. or 10 cl. = 100 Cc.

MEASURES OF WEIGHT

1 Kilogramme = 1000 Grammes.
1 Gramme = 10 decigrammes, dg. = 100 centigrammes, cg.
= 1000 milligrammes, mg.

APOTHECARIES' WEIGHT

1 Pound, lb. = 12 Ounces, = 5760 Grains, grn.
1 Ounce, \mathfrak{z} = 8 Drams, = 480 Grains, grn.
1 Dram, \mathfrak{ss} = 3 Scruples, = 60 Grains, grn.
1 Scruple, \mathfrak{d} = 20 Grains, grn.

APOTHECARIES' FLUID MEASURE

WINE MEASURE

1 Gallon, Cong. = 8 Pints, = 128 Fluidounces.
1 Pint, O. = 16 Fluidounces. 16
1 Fluidounce, $\mathfrak{f}\mathfrak{z}$ = 8 Fluidrams, = 480 Minims, m .
1 Fluidram, $\mathfrak{f}\mathfrak{ss}$ = 60 Minims, m .

The Apothecaries' ounce and grain are of the same value as the now obsolete English Troy ounce and grain. The term "Troy Weight" is frequently used when Apothecaries' weight is intended.

AVOIRDUPOIS WEIGHTS

- 1 Pound, lb. = 16 Ounces, = 7000 Grains, grn.
1 Ounce, oz. = 437.5 Grains, grn.

IMPERIAL MEASURE

- 1 Gallon, C. = 8 Pints, = 160 Fluidounces.
1 Pint, O. = 20 Fluidounces.
1 Fluidounce, fl. oz. = 8 Fluidrams, fl. dr. = 480 Minims, ℥.
The Imperial gallon contains 10 Avoirdupois pounds of distilled water at 15.6° C. The fluidounce therefore contains 437.5 grains.

The Apothecaries' Fluidounce of distilled water weighs, in vacuo, at 4° C. (39.2° F.), 456.392 grains. It weighs in air, at 15.6° C. (60° F.), 455.7 grains.

A cubic centimeter of distilled water when weighed in vacuo at 4° C. (39.2° F.), weighs 1 gramme; when weighed in air at 15.6° C. (60° F.), it weighs 0.998 gramme.

APPROXIMATE MEASURES

- One tumblerful equals about 8 fluidounces, or 240 Cc.
One teacupful equals about 4 fluidounces, or 120 Cc.
One wineglassful equals about 2 fluidounces, or 60 Cc.
One tablespoonful equals about 4 fluidrams, or 16 Cc.
One dessertspoonful equals about 2 fluidrams, or 8 Cc.
One teaspoonful equals about 1 fluidram, or 4 Cc.
One drop is usually considered equal to one minim; but it varies in size from three-fourths of a drop to four drops in one minim.

APPROXIMATE EQUIVALENTS

The following equivalents are not exact, but are sufficiently accurate for all practical purposes:

- 1 Gramme equals 15.432 Grains.
1 " " 0.035 Avoirdupois Ounce.
1 " " 0.032 Apothecaries' Ounce.
1 Cubic Centimeter equals 16.23 Apothecaries' Minims.
1 " " 16.9 Imperial Minims.
1 " " 0.0338 Apothecaries' Fluidounce.
1 " " 0.035 Imperial Ounce.
1 Grain equals 64.8 Milligrammes.
1 " " 1.053 Minims.
1 " " 1.097 Imperial Minims.
1 Meter = 39.37 Inches.

1	Apothecaries' Ounce	equals	31.1	Grammes.
1	"	"	"	1.097 Avoirdupois Ounces.
1	"	"	"	1.053 Fluidounces.
1	Avoirdupois Ounce	equals	28.35	Grammes.
1	"	"	"	0.911 Apothecaries' Ounce.
1	"	"	"	0.961 Fluidounce.
1	"	"	"	1 Imperial Fluidounce.
1	Minim	equals	0.9493	Grain.
1	"	"	"	1.04 Imperial Minims.
1	"	"	"	0.0613 Cubic centimeter.
1	Imperial Minim	equals	0.9114	Grain.
1	"	"	"	0.96 Apothecaries' Minim.
1	"	"	"	0.059 Cubic centimeter.
1	Imperial Fluidounce	equals	28.35	Cubic centimeters.
1	Imperial Fluidounce	equals	0.96	Apothecaries' Fluidounce.
1	Apothecaries' Fluidounce	equals	29.57	Cubic centimeters.
1	"	"	"	1.04 Avoirdupois Ounces.
1	"	"	"	0.95 Apothecaries' Ounce.
1	"	"	"	1.04 Imperial Fluidounces.

1.—ADDITION, SUBTRACTION, MULTIPLICATION, AND DIVISION OF WEIGHTS AND MEASURES

Abstract numbers increase and decrease in a tenfold ratio, while with compound numbers the scale varies with each denomination.

1.—*Example*.—Add 4 pounds, 6 ounces, 5 drams, and 2 pounds, 8 ounces, and 3 drams (Apothecaries).

4 lbs.	6 oz.	5 dr.
2	8	3
7	3	

The sum of the first term is 8 dr. or 1 oz., which added to the next higher denomination makes 15 oz. or 1 lb. 3 oz., 1 lb. added to the next higher denomination makes 7 lb.

The operation may also be performed by reducing the terms to the same denomination and proceeding as in simple numbers, as follows:—

$$\begin{array}{rcl}
 4 \text{ lb.} & = & 4 \times 12 \times 8 = 384 \text{ dr.} \\
 6 \text{ oz.} & = & 6 \times 8 = 48 \text{ " } \\
 2 \text{ lb.} & = & 2 \times 12 \times 8 = 192 \text{ " } \\
 8 \text{ oz.} & = & 8 \times 8 = 64 \text{ " } \\
 & & 5 + 3 = 8 \text{ " } \\
 & & \hline
 & & 696 \text{ " } = 7 \text{ lb. 3 oz.}
 \end{array}$$

Rule.—To add, subtract, multiply or divide weights and measures, reduce the terms to the same denomination and proceed as in simple numbers.

PROBLEMS

2.—What is the weight of a mixture containing 4 ounces, 5 drams, 20 grains, 8 ounces, 410 grains, 7 drams and 50 grains?

Ans. 1 lb. 2 oz. 4 dr.

3.—What is the weight of compound powder of liquorice formed by mixing the following:—Senna 6 ounces; glycyrrhiza 7 ounces, 6 drams, 40 grains; sulphur 2 ounces, 5 drams, 8 grains; oil of fennel 1 dram, 2 grains; and sugar 16 ounces, 5 drams, 8 grains?

Ans. 2 lb. 9 oz. 1 dr. 58 gr.

4.—If you have 1 pound, 6 ounces and 4 drams of rhubarb and dispense 4 ounces and 2 drams at one time, and 3 ounces 5 drams and 50 grains at another time, how much will remain?

Ans. 10 oz. 4 dr. 10 gr.

5.—If you purchase a gallon of alcohol and sell at different times 1 ounce, $\frac{1}{2}$ pint, $2\frac{1}{2}$ ounces, 6 ounces, 2 pints, 4 ounces, and 6 drams, how much will remain?

6.—What is the cost of 12 bars of soap at 30 cents a pound if each bar weighs 5 pounds and 6 ounces?

7.—Divide 9 gallons, 8 pints and 10 ounces into 5 equal quantities.

8.—If a gallon mixture requires 1 pound, 4 ounces and 6 drams of drug, how many gallons of the mixture can be made from 12 lbs. 6 ounces and 6 drams of the drug?

2.—TO DETERMINE QUANTITIES USED IN MANUFACTURING

1.—*Example.*—How many grammes of each ingredient are required in the manufacture of 35 grammes of Compound Chalk Powder? The U. S. P. gives the following proportions:

Prepared Chalk.....	30	Gm.
Acacia.....	20	Gm.
Sugar.....	50	Gm.

To make 100 Gm.

The quantity to be made, 35 grammes, is $\frac{35}{100}$ of 100 grammes. Hence we must take $\frac{35}{100}$ of the amount given for each ingredient and we have as follows: Prepared chalk 10.5 grammes, acacia 7 grammes, and sugar 17.5 grammes.

Rule.—Divide the amount to be made by the total quantity given in the formula, and multiply the amount of each ingredient by this quotient.

PROBLEMS

How much of each ingredient must be used in the manufacture of the following pharmacopœial preparations:

2.—To make 120 Compound Cathartic Pills?

Ans. Comp. ext. colocynth 9.6 Gm., mild mercurous chloride 7.2 Gm., resin of jalap 2.4 Gm., gamboge 1.8 Gm.

3.—To make 300 grammes of Comp. Powder of Glycyrrhiza?

Ans. Senna 54 Gm., liquorice 70.8 Gm., sulphur 24 Gm., oil of fennel 1.2 Gm., sugar 150 Gm.

4.—To make 1250 cubic centimeters of Compound Spirit of Orange? Ans. Oil of orange 250 Cc., oil lemon 62.5 Cc., oil of coriander 25 Cc., oil of anise 6.25 Cc., alcohol, sufficient.

5.—To make 4.5 liters of Aromatic Elixir? Ans. Comp. Spt. of Orange 54 Cc., syrup 1687.5 Cc., calcium phosphate 67.5 Gm.

6.—If you wish to use 11 grammes of mercury in the manufacture of Mass of Mercury, how much of the other constituents must be used?

Note.—Proceed as above, except that the quantity of mercury to be used is divided by the quantity of mercury given in the formula. The quantities of the other ingredients are multiplied by this quotient.

Ans. Glycyrrhiza, 3.33; althæa, 5.00; glycerin, 1, and honey of rose, 11.00 grammes.

7.—How many grammes of opium and sugar of milk must be mixed with 25 grammes of ipecac to make Dover's Powder?

Ans. Opium, 25 Gm.; sugar milk, 200 Gm.

8.—What quantity of each ingredient is required to compound the following prescription:

	Ans.
R Quinina sulphatis.....grn. ij	240 grn.
Ferri reducti.....grn. j	120 grn.
Acidi arsenosi.....grn. $\frac{1}{10}$	3 grn.
Strychnina sulphatis.....grn. $\frac{1}{10}$	2 grn.
Pulveris ipecacuanhæ.....grn. $\frac{1}{2}$	15 grn.

For one pill. Make 120 such pills.

9.—What is the dose of each ingredient in the following prescriptions?

R	Sodii bromidi	grn. clx	Ans.
	Potassii bromidi	grn. lxiiv	5 grn.
	Aquæ destillatæ	fl. oz. iv	2 grn.
	Sig. Teaspoonful at bed time.		

R	Extracti colocynthidis	grn. iv	Ans.
	Aloes	grn. xlviii	$\frac{1}{2}$ grn.
	Resinæ scammonii	grn. xxxvj	2 grn.
	Olei caryophylli	grn. vj	$1\frac{1}{2}$ grn.
	Divide into 24 pills.		

10—R	Strychninæ nitratis	grn. ij	Ans.
	Liquoris acidi arsenosi	fl. dr. ij	$\frac{1}{4}$ grain.
	Aquæ	q. s. ad fl. oz. iij	5 minims.
	S. Teaspoonful three times a day.		

3.—TO CHANGE WEIGHTS AND MEASURES FROM ONE SYSTEM TO THOSE OF ANOTHER

Troy, Apothecaries' and Avoirdupois weights, Wine and Imperial measures may be changed from one to the other as follows:

1.—*Example*.—Convert 10 ounces and 2 drams Apothecaries' weight into Avoirdupois weight.

Since there are 480 grains in 1 Apothecaries' ounce, there are 4800 grains in 10 ounces. In 2 drams there are 120 grains. $4800 \text{ grn.} + 120 \text{ grn.} = 4920 \text{ grn.}$, and $4920 \text{ grn.} \div 437.5$ (the number of grains in an Avoirdupois ounce) = 11 Avoirdupois ounces and 107.5 grains.

Rule.—Reduce the given denominations to grains and divide by the number of grains in the denominations of the desired system.

2.—Change 10.5 Apothecaries' ounces to fluidounces.
Ans. 11 oz., 25.9 Min.

3.—Change 5 pints Wine measure to Imperial measure.
Ans. 4 pints, 3 ounces and 96 Min.

4.—Change 5 pounds, 8 ounces Avoirdupois to Apothecaries' weight.
Ans. 80 oz., 100 grains.

5.—Change 34 ounces, Apothecaries' weight, to Avoirdupois weight.
Ans. 2 lbs., 5 oz., 132.5 grains.

$$6 \text{ pt.} + 13 \frac{3}{4} + 460.8 \text{ m}$$

6.—Convert 1 gallon Wine measure into Imperial measure.

Ans. 6 pts., 13 oz., 153.6 Min.

7.—Convert 4 Imperial pints into Wine measure.

8.—Change 5 Avoirdupois pounds to Wine measure.

9.—Change 60 Apothecary ounces into Wine measure.

10.—Change 10 Wine gallons into Avoirdupois weights.

4.—TO CHANGE WEIGHTS AND MEASURES BY THE USE OF EQUIVALENTS FROM ONE SYSTEM TO THOSE OF ANOTHER

1.—*Example.*—Change 10.5 Apothecaries' ounces to Avoirdupois ounces.

The equivalent of one Apothecaries' ounce is 1.097 Avoirdupois ounces. $10.5 \times 1.097 = 11.518$ or nearly $11\frac{1}{2}$ Avoirdupois ounces.

Rule.—Multiply each term by its equivalent in the desired system. (See table of equivalents.)

2.—Change 5 Wine pints to Imperial measure.

Ans. 83.2 oz. or 4 pts., 3 oz., 1 dr., 36 min.

3.—Convert 20 fluidounces into cubic centimeters.

Ans. 591.4 Cc.

4.—Convert 5000 cubic centimeters into fluidounces.

Ans. 169 fluidounces.

5.—Change 800 grammes to Avoirdupois weight.

Ans. 28 Av. oz.

6.—Convert 12 Avoirdupois ounces into grammes.

Ans. 340.194 Gm.

7.—Convert 650 grammes into Apothecaries' weight.

Ans. 20 oz., 6 dr., 24 grains.

8.—Convert 7.5 Apothecaries' ounces into grammes.

9.—What is the volume of 10 Avoirdupois pounds of water?

10.—What is the Avoirdupois weight of a gallon of water?

11.—How many cubic centimeters are there in a gallon of water?

12.—What is the cost of 12 2-grain powders of codeine sulphate, when one ounce costs \$5.30?

13.—The British Pharmacopœia formula for Syrup is: "Refined sugar, 5 pounds; boiling distilled water, 2 pints. Heat until dissolved, and add boiling distilled water to 7.5 pounds."

Change the quantities to Apothecaries' weight and Wine measure.

14.—Change the following to Apothecaries' weight and wine measure.

BELLADONNA LINIMENT

Camphor..... 50 Gm.
Fl. Ext. Belladonna..... to make 1000 Cc.

Ans. Camphor 771.6 grn., fl. ext. belladonna 33 oz. 6 dr. 24 min.

15.—Change the following formula for soap liniment to Imperial weights and measures:

		Ans.
Soap.....	60 Gm.	2 oz. 50.9 grn.
Camphor.....	45 Gm.	1 oz. 251.56 grn.
Oil Rosemary.....	10 Cc.	2 dr. 48 min.
Alcohol.....	725 Cc.	25 oz. 3 dr.
Water.....	to make 1000 Cc.	35 oz.

16.—Change the following prescriptions to the Metric system:

		Ans.
R Acetanilidi.....	grn. xxxvj	2.3328 Gm.
Potassii bromidi.....	grn. xxiv	1.5552 Gm.
Caffeinae citrate.....	grn. xij	0.7776 Gm.
Divide in 12 powders.		

17.—Change to Apothecaries' weights and measures.

		Ans.
R Codeinae sulphatis.....	0.13 Gm.	2+grn.
Ammonii chloridi.....	8. Gm.	120.456 grn.
Syrupi tolutani.....	60. Cc.	2.03 oz.
Aquæ.....	ad 90. Cc.	3.04 oz.

Note.—When changing weights and measures from one system to those of another by the use of equivalents, the answer frequently contains a decimal which may be eliminated by multiplying the decimal by the number of units of a lower denomination required to make one of the given denomination.

For example: If the answer is 12.84 Avoirdupois ounces. The decimal (.84) may be changed to grains by multiplying by 437.5, the number of grains in one Avoirdupois ounce; thus $0.84 \times 437.5 = 367.5$ grains.

THERMOMETERS—TEMPERATURE

Three kinds of thermometers are used for measuring heat: Fahrenheit, Centigrade, and Réaumur. The first is the domestic thermometer of the United States and Great Britain. The second is used for scientific purposes; the third is rarely used in this country.

The boiling point of water is 212° F., 100° C., 80° R. The freezing point of water is 32° F., 0° C., 0° R. The difference between the freezing- and the boiling-point of water is 180° F., 100° C., and 80° R.

Since 180° F. are equal to 100° C., each degree F. is equal to $\frac{10}{9}$ of a degree centigrade or $\frac{8}{9}$ of a degree Réaumur. In a similar manner we find that one degree Centigrade is equal to $\frac{9}{5}$ of a degree Fahrenheit, or, $\frac{4}{5}$ of a degree Réaumur. One degree Réaumur is equal to $\frac{5}{4}$ of a degree Fahrenheit, or, $\frac{4}{5}$ of a degree Centigrade.

5.—TO CONVERT FAHRENHEIT TO CENTIGRADE

1.—*Example.*—Convert 140° Fahrenheit to Centigrade.

$$140^{\circ} - 32^{\circ} = 108^{\circ}; \frac{5}{9} \text{ of } 108^{\circ} = 60^{\circ}, \text{ or } 108^{\circ} \div 1.8 = 60^{\circ}.$$

Rule.—Subtract 32 and multiply by $\frac{5}{9}$ (or divide by 1.8).

PROBLEMS

					Ans.
✓ 2.—	Convert	68°	Fahrenheit	to Centigrade.	20° C.
3.—	"	23°	"	"	-5° C.
✓ 4.—	"	-22°	"	"	-30° C.
5.—	"	390°	"	"	198.88° C.
✓ 6.—	"	244°	"	"	
7.—	"	-40°	"	"	
✓ 8.—	"	70°	"	"	

6.—TO CONVERT CENTIGRADE TO FAHRENHEIT

1.—*Example.*—Convert 210° Centigrade to Fahrenheit.

$$\frac{9}{5} \text{ of } 210^{\circ} = 378^{\circ}; 378^{\circ} + 32^{\circ} = 410^{\circ} \text{ C., or } 210^{\circ} \times 1.8 + 32^{\circ} = 410^{\circ} \text{ C.}$$

Rule.—Multiply by $\frac{9}{5}$ (or by 1.8), and add 32.

PROBLEMS

					Ans.
✕ 2.—	Convert	250°	Centigrade	to Fahrenheit.	482° F.
3.—	"	-40°	"	"	-40° F.
✕ 4.—	"	30°	"	"	86° F.
5.—	"	-10°	"	"	14° F.
✕ 6.—	"	-30°	"	"	-22° F.
7.—	"	-40°	"	"	"
✕ 8.—	"	22°	"	"	"

7.—TO CONVERT CENTIGRADE TO RÉAUMUR

1.—*Example.*—Convert 80° Centigrade to Réaumur.
 $\frac{4}{5}$ of 80° = 64° R.

Rule.—Multiply by $\frac{4}{5}$ or by 0.8.

PROBLEMS

					Ans.
✕ 2.—	Convert	72.5°	Centigrade	to Réaumur.	58° R.
3.—	"	350°	"	"	280° R.
4.—	"	-40°	"	"	-32° R.
5.—	"	25°	"	"	"

8.—TO CONVERT RÉAUMUR TO CENTIGRADE

1.—*Example.*—Convert 80° Réaumur to Centigrade.
 $\frac{5}{4}$ of 80° = 100° R.

Rule.—Multiply by $\frac{5}{4}$ or by 1.25.

PROBLEMS

					Ans.
✕ 2.—	Convert	640°	Réaumur	to Centigrade.	800° C.
3.—	"	48°	"	"	60° C.
4.—	"	-12°	"	"	-15° C.
5.—	If water boils at 80° Réaumur what is the boiling-point in Centigrade degrees?				

9.—TO CONVERT FAHRENHEIT TO RÉAUMUR

1.—*Example.*—Convert 77° Fahrenheit to Réaumur.
 $77° - 32° = 45°$; $\frac{4}{9}$ of 45° = 20° R.

Rule.—Subtract 32 and multiply by $\frac{4}{9}$ or divide by 2.25.

PROBLEMS

					Ans.
2.—	Convert 95° Fahrenheit to Réaumur degrees	28° R.			
3.—	" -13° " " " "	-20° R.			
4.—	" 23° " " " "				
5.—	" 70° " " " "				

10.—TO CONVERT RÉAUMUR TO FAHRENHEIT

1.—*Example.*—Convert 80° Réaumur to Fahrenheit.

$\frac{5}{4}$ of 80° + 32° = 212° F.

Rule.—Multiply by $\frac{5}{4}$ or by 2.25, and add 32.

PROBLEMS

					Ans.
2.—	Convert 32° Réaumur to Fahrenheit.	104° F.			
3.—	" 96° " " " "	248° F.			
4.—	" -16° " " " "	-4° F.			
5.—	" -8° " " " "				
6.—	" 14° " " " "				

SPECIFIC GRAVITY

It is not the purpose of this work to enter into the details of taking specific gravity, but rather to give problems illustrating the methods of calculating the results of manipulation.

Specific gravity may be defined as the relative weight of equal bulks or volumes of different bodies, water being taken as the standard. The object sought is always the weight of a volume of water equal to that of the substance, the specific gravity of which we wish to obtain, whether that substance be liquid or solid, soluble or insoluble, heavier or lighter than water.

SPECIFIC GRAVITY HYDROMETERS

The specific gravity of liquids is usually taken with hydrometers or specific gravity flasks (pycnometers).

Hydrometers are instruments which, when floating in a liquid, show the specific gravity, density, or per cent., on a scale. The specific gravity hydrometer is so constructed that the number at the surface of the liquid represents the specific gravity. Hydrometers for liquids heavier than water are graduated from 2000 at the bottom, to 1000 at the top. That the reading may be more exact, it is customary to use five hydrometers for liquids heavier than water. The first is graduated from 1000 to 1200, the

second from 1200 to 1400, the third from 1400 to 1600, the fourth from 1600 to 1800, and the fifth from 1800 to 2000.

For liquids lighter than water, the hydrometer is graduated from 1000 at the bottom to 700 at the top.

The specific-gravity hydrometer should sink in pharmacopœial hydrochloric acid to 1158, in sulphuric acid to 1840, in alcohol to 816 and in ether to 716. By pointing off three decimal places, if the instrument is not so marked, we have the respective specific gravities without calculation.

Hydrometers giving the per cent. by weight or volume are constructed for special purposes, as alcoholometers, which are so graduated that the reading gives the actual per cent. of absolute alcohol that the liquid contains.

BAUMÉ HYDROMETERS

Baumé hydrometers are constructed for use in both light and heavy liquids. The scale gives arbitrary degrees, which may be converted into specific gravity as follows:—

11.—FOR LIQUIDS HEAVIER THAN WATER

1.—*Example.*—Change 60° Baumé to specific gravity.

$$\frac{145}{145-60} = \frac{145}{85} = 1.7058 \text{ Sp. Gr.}$$

Rule.—Divide 145 by 145 minus the given number of degrees.

2.—What is the specific gravity of hydrochloric acid, 20° Baumé? Ans. 1.16 Sp. Gr.

3.—To what point will a specific gravity hydrometer sink in glycerin when a Baumé hydrometer sinks to 29°? Ans. 1.25°.

4.—What is the specific gravity of sulphuric acid, 45° Baumé?

5.—If a Baumé hydrometer sinks to 35° in a solution of sugar, what is the specific gravity of the syrup?

12.—FOR LIQUIDS LIGHTER THAN WATER

1.—*Example.*—Change 56° Baumé to specific gravity.

$$\frac{140}{130+56} = \frac{140}{186} = 0.752 \text{ Sp. Gr.}$$

Rule.—Divide 140 by 130 plus the given degrees.

PROBLEMS

X 2.—What is the specific gravity of ammonia water, 24° Baumé? Ans. 0.909.

3.—What is the specific gravity of alcohol, 40° Baumé?

Y 4.—Change 60° Baumé to specific gravity.

TO CHANGE SPECIFIC GRAVITY DEGREES TO BAUMÉ

13.—FOR LIQUIDS LIGHTER THAN WATER

1. *Example.*—Change specific gravity 0.750 to Baumé.

$$\frac{140}{0.750} - 130 = 56.66 \text{ Bé.}$$

Rule.—Divide 140 by the specific gravity and subtract 130.

PROBLEMS

Y 2.—What is the degree Baumé of ammonia which has a specific gravity of 0.9655? Ans. 15° Bé.

3.—Change the following specific gravities to Baumé degrees:—0.765, 0.979, 0.909, 0.800.

14.—FOR LIQUIDS HEAVIER THAN WATER

1.—*Example.*—Change specific gravity 1.24 to Baumé degrees.

$$145 - \frac{145}{1.24} = 28.1^\circ \text{ Baumé.}$$

Rule.—From 145 subtract 145 divided by the specific gravity.

Y 2.—How many degrees Baumé is sulphuric acid which has a specific gravity of 1.84? Ans. 66.2° Bé.

3.—What are the degrees Baumé of a syrup having a specific gravity of 1.124? Ans. 15.997° Bé.

4.—Change specific gravities 1.576 and 1.45 to Baumé degrees.

15.—TO CHANGE TWADDELL DEGREES TO SPECIFIC-GRAVITY DEGREES

Twaddell's hydrometer is for liquids heavier than water. Each degree equals 0.005 of a specific gravity degree.

1.—What is the specific gravity of sulphuric acid if Twaddell's hydrometer floats at 168°?

$168 \times 0.005 + 1 = 1.84$ specific gravity.

Rule.—Multiply the degrees by 0.005 and add 1.

✕ 2.—Change the following Twaddell's degrees to specific gravity; 50°, 80°, and 125°.

16.—TO CHANGE SPECIFIC GRAVITY TO TWADDELL DEGREES

1.—*Example.*—What degree, Twaddell, is hydrochloric acid, specific gravity, 1.16?

$$\frac{1.16 - 1}{0.005} = 32^\circ \text{ T.}$$

Rule—Subtract 1 from the specific gravity and divide by 0.005.

PROBLEMS

✕ 2.—To what degree will a Twaddell's hydrometer sink in the following pharmacopœial preparations: Nitric acid, solution ferric chloride, and syrup? 1.4

1.32

1.313

17.—SPECIFIC GRAVITY FLASKS OR PYCNOMETERS

The majority of specific-gravity flasks are constructed to hold 25, 50, or 100 grammes at a given temperature, and in some cases 250, 500, and 1000 grains, but the latter are rapidly passing out of use. When the flask holds exactly 100 grammes of water at the proper temperature, the same flask will hold 71.6 grammes of ether or 149 grammes of chloroform, which, if divided by 100, will give the specific gravity of each liquid. Therefore, when the same flask is filled with any liquid, we have only to divide the weight of the contents of the flask by 100 to obtain the specific gravity. In like manner, if the flask contains 25 grammes of water we have only to multiply the weight of its contents, when filled with *any liquid*, by 0.04, or to divide by 25, to obtain the specific gravity.

An ordinary light flask holding from 20 to 100 grammes may be used in taking the specific gravity of liquids. The flask is dried and weighed, filled with water at the proper temperature and weighed again, and the weight of the flask subtracted; the difference is the weight of the water. In the same manner find the weight of the contents of the flask when filled with any desired liquid.

1.—*Example.*—A flask weighs 20 grammes; when filled with water it weighs 44 grammes, and when filled with glycerin 50 grammes. What is the specific gravity of the glycerin?

Subtracting the weight of the bottle in each case, we have 24 grammes as the weight of the water, and 30 grammes as the weight of the glycerin. $30 \div 24 = 1.25$, the sp. gr. of the glycerin.

Rule.—Divide the weight of the substance by the weight of an equal bulk or volume of water. The quotient is the specific gravity.

PROBLEMS

2.—How many grammes of glycerin, sp. gr. 1.25, will a 100-gramme flask hold? Ans. 125 grammes.

3.—A flask holds 25 grammes of water. The same flask holds 29 grammes of hydrochloric acid. What is the specific gravity of the acid? Ans. 1.16 sp. gr.

4.—How many grammes of chloroform, specific gravity 1.49, will a 50-Cc. flask hold? Ans. 74.5 grammes.

5.—If a bottle holds 1826 grammes of sulphuric acid, U. S. P., how many grammes of water will it hold?

Ans. 1000 grammes.

6.—If 250 Cc. of ether weighs 181.25 grammes, what is the specific gravity of the ether? Ans. 0.725 sp. gr.

7.—What is the specific gravity of syrup when a fluidounce weighs 600.1 grains.

8.—What is the specific gravity of alcohol, when one liter weighs 820 Gm.?

9.—What is the specific gravity of aqua ammonia, when a bottle holds 50 grammes of water or 48 grammes of aqua ammonia?

10.—A bottle weighing one Apothecaries' ounce, when filled with water, weighs 2 oz. 6 dr. and 48 grains; when filled with hydrochloric acid it weighs 3 ounces. What is the specific gravity of the acid?

18.—TO TAKE THE SPECIFIC GRAVITY OF LIQUIDS WITH A PLUMMET

The specific gravity of liquids may be found by weighing a solid in water, and again in the liquid of which the specific grav-

ity is desired. If a solid body be weighed in water and also in air, the difference in the weights is the weight of a volume of water equal to the volume of the solid. If the same solid is weighed in any other liquid and the weight subtracted from the weight in air, the difference is the weight of a volume of liquid equal to the volume of the solid, or to the weight of the same volume of water.

1.—*Example*.—A piece of glass weighing 39 grammes in air weighs 24 grammes in water, and 20.25 grammes in glycerin. What is the specific gravity of the glycerin?

$39 - 24 = 15$, the weight of water displaced.

$39 - 20.25 = 18.75$, the weight of glycerin displaced.

$18.75 \div 15 = 1.25$, the specific gravity of the glycerin.

Rule.—Weigh the solid in air, in water, and in the liquid. The loss of weight in the liquid divided by the loss of weight in the water is the specific gravity.

PROBLEMS

✓ 2.—A piece of glass weighs 39 grammes in air, 24 grammes in water, and 27.75 grammes in ether. What is the specific gravity of the ether? Ans. 0.750 sp. gr.

✓ 3.—The same piece of glass weighs 16.65 grammes in chloroform. What is the specific gravity of the chloroform?

Ans. 1.49 sp. gr.

✓ 4.—If the same piece of glass weighs 27.6 grammes less in sulphuric acid than in air, what is the specific gravity of the acid?

Ans. 1.84 sp. gr.

✓ 5.—56.75 grammes of lead weighs 51.75 grammes in water, and 52.5 grammes in alcohol. What is the specific gravity of the alcohol?

✓ 6.—A piece of copper loses 14 grammes when weighed in water, and 17.5 grammes when weighed in glycerin. What is the specific gravity of the glycerin?

Note.—If a piece of glass be made of such a size that it will displace exactly 10 grammes of water, then the loss of weight in any liquid divided by ten will give the specific gravity. If the specific gravity of glass is 2.600, then a piece weighing 26 grammes will displace 10 grammes of water, 12.4 grammes of glycerin, or 7.16 grammes of ether.

19.—TO DETERMINE THE SPECIFIC GRAVITY OF SOLIDS INSOLUBLE IN, BUT HEAVIER THAN, WATER

Weigh the solid in air. Suspend in water by means of a silk thread, and weigh again. The difference in weight is the weight of the water displaced, and is equal in volume to the volume of the solid.

1.—*Example*.—A piece of native lead sulphide weighs in air 108.75 grammes, in water 93.75 grammes. What is its specific gravity?

$$108.75 - 93.75 = 15. \quad 108.75 \div 15 = 7.25 \text{ sp. gr.}$$

Rule.—Divide the weight in air by the loss of weight in water. The quotient is the specific gravity.

PROBLEMS

2.—What is the specific gravity of a piece of lead weighing 35.412 grammes in air and 32.292 grammes in water?

Ans. 11.35 sp. gr.

3.—A piece of copper weighs 34.008 grammes in water, and 38.333 grammes in air. What is the specific gravity?

Ans. 8.862 sp. gr.

4.—What is the weight of water displaced by a piece of silver, specific gravity 10.25, which weighs 27.162 grammes in air?

5.—What is the weight of a piece of silver, specific gravity 10.25, which displaces 5 grammes of water?

20.—SOLIDS INSOLUBLE IN, BUT LIGHTER THAN, WATER

Weigh the substance in air and attach it to a sinker of known weight. Weigh in water and subtract the weight of both in water from the weight of both in air. The difference is the loss in weight of both in water. Find separately what the sinker loses in water and subtract this from what they both lose in water. The difference is the loss in weight of the substance in water.

1.—*Example*.—A piece of lead weighs 11.35 grammes in air, and 10.35 grammes in water. The lead is attached to a piece of wax weighing 2.16 grammes in air, and their weight, taken together in water, is 10.26 grammes. Find the specific gravity of the wax.

$11.35 + 2.16 = 13.51$, the weight of both in air.

$13.51 - 10.26 = 3.25$, the loss in weight of both in water.

$11.35 - 10.35 = 1$, the loss in weight of the sinker in water.

$3.25 - 1 = 2.25$, the loss in weight of the wax in water.

$2.16 \div 2.25 = 0.96$, the sp. gr. of the wax.

Rule.—Divide the weight of the substance in air by the loss in weight of both in water, minus the loss in weight of the sinker in water.

A somewhat shorter method is the following:

Weigh the substance in air; weigh the sinker in water. Attach the substance to the sinker, and weigh both in water.

Take the above example without the weight of the sinker in air.

$10.35 + 2.16 = 12.51$, the weight of the sinker in water plus the weight of the substance in air.

$12.51 - 10.26 = 2.25$, the loss in weight of the wax in water.

$2.16 \div 2.25 = 0.96$, the sp. gr. of the wax.

Rule.—Add the weight of the substance in air to the weight of the sinker in water. From this amount subtract the weight of the substance and sinker together in water. The difference is the weight of the water displaced by the substance. Divide the weight in air by the weight of water displaced.

PROBLEMS

2.—A piece of lead weighs 17.706 grammes in air and 16.146 grammes in water. A piece of spermaceti weighs 14.65 grammes in air. Spermaceti and lead in water weigh 15.296 grammes. What is the specific gravity of the spermaceti?

Ans. 0.945 sp. gr.

3.—Weight of wax in air..... 5 Gm.

“ “ sinker in air..... 20 Gm.

“ “ “ “ water..... 18 Gm.

“ “ “ and wax in water..... 17.8 Gm.

Find the specific gravity of the wax. Ans. 0.96 sp. gr.

4.—A cork weighs 9 grammes in air. A sinker weighs 38 grammes in water. The cork and sinker together weigh 3.25 grammes in water. What is the specific gravity of the cork?

Ans. 0.2057 sp. gr.

✓5.—A piece of copper weighs 17.68 grammes in air, and 15.68 grammes in water. A piece of cacao butter weighs 12.125 grammes in air. The copper and cacao butter together weigh 15.305 grammes in water. What is the specific gravity of the cacao butter?

✓6.—A piece of paraffin weighs 13.80 grammes. A piece of brass weighs 9 grammes in water. The paraffin and brass together weigh 7.8 grammes in water. What is the specific gravity of the paraffin?

✓7.—What is the specific gravity of a piece of wood which weighs 18 grammes. When attached to a piece of brass and suspended in water, both weigh 3.6 grammes. The brass weighs 7 grammes in water?

21.—TO FIND THE SPECIFIC GRAVITY OF POWDERS INSOLUBLE IN WATER

Fill a specific-gravity flask with water and weigh; empty the flask, introduce a weighed quantity of the powder, fill with water and weigh again. Add the weight of the powder to the weight of the flask filled with water, and from this amount subtract the weight of the flask containing the powder and water. The difference is the weight of water displaced.

1.—*Example*.—A bottle filled with water weighs 58 grammes. The bottle containing 12 grammes of sand and filled with water weighs 65.2 grammes. Find the specific gravity of the sand.

$$58 + 12 = 70.$$

$$70 - 65.2 = 4.8, \text{ the weight of water displaced.}$$

$$12 \div 4.8 = 2.5, \text{ the sp. gr. of the sand.}$$

Rule.—Divide the weight of the powder by the weight of water displaced. The quotient is the specific gravity.

PROBLEMS

2.—Place 56.75 grammes of lead shot in a specific-gravity flask. The flask is then filled with water and is found to weigh 116.75 grammes. The flask filled with water weighs 65 grammes. What is the specific gravity of the shot? Ans. 11.35 sp. gr.

3.—A bottle filled with water weighs 24 grammes. If 13.8 grammes of granulated zinc be introduced into the bottle, and the bottle filled with water, the combined weight will be 35.8 grammes. What is the specific gravity of the zinc?

Ans. 6.9 sp. gr.

4.—How many grammes of water will be displaced by 1035 grammes of zinc, specific gravity 6.9? Ans. 150 Gm.

5.—Weight of mercuric oxide..... 38.5 Gm.

Weight of bottle filled with water..... 35 Gm.

Weight of bottle containing mercuric
oxide, when filled with water..... 70 Gm.

Find the specific gravity of the mercuric oxide.

Ans. 11 sp. gr.

6.—When 33.488 grammes of mercuric sulphate are placed in a bottle and the bottle filled with water, the combined weight is 68.79 grammes. The weight of the bottle filled with water is 40.502 grammes. What is the specific gravity of the mercuric sulphate?

7.—How many grains of water will be displaced by an Avoirdupois pound of mercury, specific gravity 13.56?

8.—How many grammes of mercury will an ounce bottle hold?

22.—TO DETERMINE THE SPECIFIC GRAVITY OF SOLIDS SOLUBLE IN WATER

The method employed is the same as in taking the specific gravity of solids insoluble in water, except that, in place of water, some other liquid is used in which the substance is insoluble, as oil, alcohol, or turpentine. A correction is then made for the difference in the specific gravity of the liquid used and that of water, by multiplying by the specific gravity of the liquid.

1.—*Example.*—A crystal of potassium dichromate weighs 19.705 grammes in air and 13.27 grammes in deodorized alcohol, specific gravity 0.816. What is the specific gravity of the potassium dichromate?

$19.705 - 13.27 = 6.435$, the loss of weight in alcohol.

$19.705 \div 6.435 = 3.062$, the specific gravity as compared with alcohol.

$3.062 \times 0.816 = 2.495$, the specific gravity as compared with water.

Rule.—Weigh the substance in air, and then in some liquid in which it is insoluble. Divide the weight in air by the loss of weight in the liquid and multiply by the specific gravity of the liquid.

PROBLEMS

2.—What is the specific gravity of copper sulphate, if a piece weighs 20.311 grammes in air and 12.359 grammes in turpentine having a specific gravity of 0.86?

Ans. 2.196 sp. gr.

3.—A piece of borax weighs 23.62 grammes in air and 12.323 grammes in alcohol, specific gravity 0.816. What is the specific gravity of the borax?

Ans. 1.706 sp. gr.

4.—A specific-gravity flask filled with chloroform weighs 98.092 grammes; 12 grammes of salt is placed in the flask and the flask filled with chloroform. The weight of the flask, salt, and chloroform is 101.64 grammes. The specific gravity of the chloroform is 1.49. What is the specific gravity of the salt?

5.—The capacity of a specific-gravity bottle is 50 grammes of water or 43.686 grammes of benzin. If 16 grammes of potassium chlorate are added to the bottle and filled with benzin the contents weigh 53.244 grammes. What is the specific gravity of the potassium chlorate?

6.—A specific-gravity bottle weighs 20.5 grammes. When filled with water it weighed 70.5 grammes; when filled with ether it weighed 56.75 grammes; 25 grammes of sugar are placed in the bottle and the latter filled with ether, it then weighs 70.279 grammes. What is the specific gravity of the sugar?

23.—TO FIND THE SPECIFIC VOLUME OF A LIQUID

Specific volume is the volumetric ratio existing between the same weights of different bodies, as compared with the volume of the same weight of water. It is, therefore, the reciprocal of specific gravity. In pharmaceutical practice its use is confined

to liquids. Specific volume may be found by dividing the volume of a given weight of the liquid by the volume of an equal weight of water.

1.—*Example*.—100 grains of glycerin measure 84 minims. 100 grains of water measure 105 minims. What is the specific volume of the glycerin?

$84 \div 105 = 0.8$, the specific volume of the glycerin.

A given weight of liquid cannot be as accurately measured as a given volume of liquid can be weighed. Therefore, a better method is to find the specific gravity and divide 1 by the specific gravity.

Example.—The specific gravity of glycerin is 1.25. $1 \div 1.25 = 0.80$, the specific volume of the glycerin.

Rule.—Find the specific gravity of the liquid and divide 1 by the specific gravity. The quotient is the specific volume.

PROBLEMS

2.—What is the specific volume of stronger ammonia water, specific gravity 0.90? Ans. 1.111 sp. vol.

3.—Find the specific volume of nitric acid, specific gravity 1.420. Ans. 0.7042 sp. vol.

4.—The specific gravity of bromine is 2.990. What is its specific volume? Ans. 0.3344 sp. vol.

5.—What is the volume of 50 grammes of chloroform, specific gravity 1.49?

6.—How many cubic centimeters in 50 grammes of ether, specific gravity 0.725?

7.—What is the specific volume of chloroform if 1000 grains measure 1.473 fluidounces, and the same weight of water measures 2.195 fluidounces?

24.—TO FIND THE VOLUME OF A GIVEN WEIGHT OF ANY LIQUID

1.—*Example*.—How many fluidounces in 50 Avoirdupois ounces of glycerin? 50×0.96 (the equivalent in fluidounces of one Avoirdupois ounce of water) = 48, which is the equivalent in fluidounces of 50 Avoirdupois ounces. 48×0.8 (the specific volume of glycerin) = 38.4 fluidounces of glycerin; or we may divide by the specific gravity instead of multiplying by the specific volume.

- (a) $50 \times 0.96 \times 0.8 = 38.4$ or,
 (b) $50 \times 0.96 \div 1.25 = 38.4$ fluidounces.

Rule.—Change the given weight to its equivalent in the desired volume, and multiply by the specific volume of the liquid, or divide by its specific gravity.

PROBLEMS

- 2.—How many fluidounces in 75 Apothecaries' ounces of sulphuric acid, sp. gr. 1.84? Ans. 42.86 fl. oz.
 3.—How many fluidounces in 150 Av. oz. of nitric acid, sp. gr. 1.42? Ans. 101.4 fl. oz.
 4.—How many fluidounces in 400 grammes of olive oil, sp. gr. 0.915? Ans. 14.78 fl. oz.
 5.—How many cubic centimeters in 600 grammes of hydrochloric acid, sp. gr. 1.16?
 6.—What is the cost of 8 fluidounces of glycerin, sp. gr. 1.25, when 10 pounds cost \$2.20?
 7.—If a 500-gramme bottle of chloroform, sp. gr. 1.49, cost \$1.10, what is the cost of 1 fluidounce?
 8.—In the following formula, change the quantities of the liquids to cubic centimeters:

		Ans.
Pepsin.....	40 Gm.	
Hydrochloric acid.....	12 "	10.344 Cc.
Glycerin.....	406.25 "	325 Cc.
Water.....	660 "	660 Cc.

- 9.—How many fluidounces will be formed by mixing a pound of chloroform with a pound of ether, no allowance being made for contraction?

25.—TO FIND THE WEIGHT OF A GIVEN VOLUME OF ANY LIQUID

- 1.—*Example.*—How many Apothecaries' ounces in 100 fl. oz. of chloroform? $100 \times 0.95 = 95$ Apothecaries' ounces. 95×1.49 , the sp. gr. of chloroform, = 141.55 Apoth. oz. of chloroform.

Rule.—Change the given volume to its equivalent in the desired weight, and multiply by the specific gravity of the liquid.

- 2.—What will one pint of chloroform, sp. gr. 1.49, cost if one pound costs 60 cents? Ans. 92.97 cents.

3.—What will one pint of ether, sp. gr. 0.716, cost if one pound cost 70 cents? Ans. 52.12 cents.

4.—What will 5 gallons of glycerin, sp. gr. 1.25, cost at 20 cents a pound? Ans. \$10.40

5.—How many pounds in one pint of mercury, sp. gr. 13.535?

6.—How many grammes in a quart of ether, sp. gr. 0.716?

7.—If 5 pints of sulphuric acid, sp. gr. 1.84, cost \$1.15, what is the cost of one pound?

8.—If glycerin, sp. gr. 1.25, costs 22 cents a pound, what is the cost of a gallon?

26.—TO FIND THE VOLUME OF PURE SUBSTANCE IN A GIVEN WEIGHT OF LIQUID WHEN THE PER CENT. BY WEIGHT IS GIVEN

1.—*Example*.—A solution contains 10 per cent. by weight of glycerin. How many fluidounces of glycerin in 40 Apothecaries' ounces of the solution?

$$40 \times 0.10 \times 1.05 \div 1.25 = 3.36 \text{ fl. oz. of glycerin.}$$

Rule.—Multiply the given weight by the per cent. The product will be the weight of pure substance. Convert into the desired volume according to section 24.

PROBLEMS

2.—How many fluidounces of absolute alcohol in 150 Apothecaries' ounces of U. S. P. dilute alcohol?

Ans. 82.7 fl. oz.

3.—How many cubic centimeters of oil of anise in 750 grammes of spirit of anise, if the spirit contains 13 per cent. of the oil, having a sp. gr. of 0.98? Ans. 99.49 Cc.

4.—How many cubic centimeters of ether, sp. gr. 0.716, and of alcohol, sp. gr. 0.816, in 810 grammes of spirit of ether, which contains 30 per cent. of ether and 70 per cent. of alcohol?

Ans. 339.37 Cc. ether, 694.85 Cc. alcohol.

5.—If white wine contains 12 per cent. by weight of alcohol, sp. gr. 0.79, how many fluidounces of alcohol are there in two quarts of wine, the specific gravity of the wine being the same as that of water? Ans. 9.721 fl. oz.

27 — TO FIND THE WEIGHT OF PURE SUBSTANCE IN A GIVEN VOLUME OF LIQUID WHEN THE PER CENT.

BY VOLUME IS GIVEN

1.—*Example*.—How many Apothecaries' ounces of absolute alcohol in 15 fluidounces of alcohol containing 60 per cent. by volume of absolute alcohol?

$15 \times 0.60 = 9$ (the volume of absolute alcohol) $\times 0.95 \times 0.797 = 6.814$ Apoth. oz. absolute alcohol.

Rule.—Multiply the given volume by the per cent. The product is the volume of pure substance. Convert this into weight according to section 25.

PROBLEMS

2.—Spirit of chloroform contains 6 cubic centimeters of chloroform in 100 cubic centimeters of the spirit. How many grammes of chloroform, sp. gr. 1.49, in 7500 cubic centimeters of the spirit?

Ans. 670.5 grammes.

3.—Spirit of cinnamon contains 10 per cent. by volume of the oil of cinnamon, which has a specific gravity of 1.06. How many grammes of the oil are required to make two and a half liters of the spirit?

Ans. 265 grammes.

4.—Liniment of ammonia contains:

Ammonia water.....	sp. gr. 0.96	35%	by volume
Alcohol.....	sp. gr. 0.82	5%	"
Cotton-seed oil.....	sp. gr. 0.92	60%	"

How many Apothecaries' ounces of each will be required to make two pints of the above liniment? Ans. Ammonia water, 10.214 oz.; Alcohol, 1.246 oz.; Cotton-seed oil, 16.78 oz.

5.—How many grammes of glycerin, sp. gr. 1.25, in 4 liters of syrup of wild cherry which contains 15 per cent. by volume of glycerin?

6.—How many pounds of chloroform, sp. gr. 1.49, in a gallon of chloroform liniment which contains 30 per cent. by volume of chloroform?

28.—TO FIND THE PER CENT. BY VOLUME WHEN THE PER CENT. BY WEIGHT IS GIVEN

1.—*Example*.—A mixture of alcohol and water, having a specific gravity of 0.9, contains 58 per cent. by weight of alcohol. What is the per cent. by volume?

A unit weight of the solution contains 0.58 of a unit weight of absolute alcohol. This 0.58 of a unit weight divided by the specific gravity of absolute alcohol equals the volume of absolute alcohol which a unit weight of the solution contains, $\frac{0.58}{0.797} = 0.7277$. The volume of a unit weight of the solution is 1 divided by its specific gravity, $\frac{1}{0.9} = 1.111$. The volume of absolute alcohol divided by the volume of the solution equals the per cent. by volume, $0.7277 \div 1.111 = 0.6549$, the per cent. by vol.

Thus, $\frac{0.58}{0.797} \div \frac{1}{0.9} = 0.6549$, or $\frac{0.58}{0.797} \times 0.9 = 0.6549$.

Rule.—Divide the weight per cent. by the specific gravity of the substance of which the per cent. is given and multiply by the specific gravity of the solution.

PROBLEMS

2.—Alcohol having a specific gravity of 0.9135 contains 52 per cent. by weight of absolute alcohol. What is the per cent. by volume? Ans. 59.6 per cent.

3.—What is the per cent. by volume of absolute alcohol in a solution having a specific gravity of 0.9623 and containing 27 per cent. by weight of absolute alcohol? Ans. 32.59 per cent.

4.—Alcohol containing 38 per cent. by weight of absolute alcohol has a specific gravity of 0.943. What is the per cent. by volume?

5.—What is the per cent. by volume of commercial alcohol, sp. gr. 0.82, in a spirit containing 54.95 per cent. by weight of commercial alcohol and having a sp. gr. of 0.9184?

6.—What is the per cent. by volume of glycerin, sp. gr. 1.25, in a mixture having a sp. gr. of 1.143 and containing 55 per cent. by weight of glycerin?

7.—If spirit of ether has a sp. gr. of 0.7972 and contains 30 per cent. by weight of ether, sp. gr. 0.725, what is the per cent. by volume?

29.—TO FIND THE PER CENT. BY WEIGHT WHEN THE PER CENT. BY VOLUME IS GIVEN

1.—*Example.*—A solution of alcohol in water having a specific gravity of 0.9 contains 66 per cent. by volume of absolute alcohol. What is the per cent. by weight?

A unit volume of the solution contains 0.66 of a unit volume of absolute alcohol. 0.66 multiplied by the specific gravity of absolute alcohol equals the weight of absolute alcohol in a unit volume of the solution: $0.66 \times 0.797 = 0.526$. The weight of a unit volume of the solution is 1 multiplied by its specific gravity, $1 \times 0.9 = 0.9$. The weight of absolute alcohol divided by the weight of the solution equals the per cent. by weight: $0.526 \div 0.9 = 0.584$.

$$0.66 \times 0.797 \div 0.9 = 0.584 \text{ or } 58.4 \text{ per cent. by weight.}$$

Rule.—Multiply the per cent. by the specific gravity of the substance of which the per cent. is given and divide by the specific gravity of the solution.

PROBLEMS

2.—Dilute alcohol having a specific gravity of 0.9264 contains 54 per cent. by volume of absolute alcohol. What per cent. by weight does it contain?

Ans. 46.45 per cent.

3.—What is the per cent. by weight of absolute alcohol in dilute alcohol having a specific gravity of 0.8557 and containing 83 per cent. by volume of absolute alcohol.

Ans. 77.3 per cent.

4.—A dilute alcohol containing 11 per cent. by volume of absolute alcohol has a specific gravity of 0.9857. What per cent. by weight of absolute alcohol does it contain?

5.—Tincture of ferric chloride has a specific gravity of 0.955 and contains 25 per cent. by volume of the solution of ferric chloride, which has a specific gravity of 1.315. What is the per cent. by weight?

6.—White wine having the same specific gravity as water contains 13 per cent. by volume of absolute alcohol. What per cent. by weight of absolute alcohol does it contain?

PERCENTAGE SOLUTIONS

30.—TO FIND THE AMOUNT OF SUBSTANCE REQUIRED TO MAKE
A GIVEN QUANTITY OF A SOLUTION WHEN
THE PER CENT. IS GIVEN

Percentage solutions are manufactured by weight. Therefore, when the quantity to be prepared is given in fluid measure, it must be changed to weight.

1.—*Example*.—Prepare two fluidounces of a four-per cent. solution of cocaine.

Two fluidounces of water weigh 911.4 grains. Four per cent. of 911.4 is 36.45 grains. 36.45 grains of cocaine are to be dissolved in sufficient water to make the total weight 911.4 grains.

Rule.—Reduce the volume to its equivalent weight and multiply by the per cent.

PROBLEMS

2.—How many grains of mercury bichloride are required to make one pint of a 0.1-per cent. solution?

Ans. 7.29 grains.

3.—How many grammes of mercury bichloride are required to make 750 cubic centimeters of a 1 : 1000 solution?

Ans. 0.75 Gm.

4.—Carbolic-acid solution, 4%.....f $\frac{3}{2}$
Boric-acid solution, 5%.....f $\frac{3}{2}$

Mix.

How many grains of boric acid and carbolic acid are required in the above prescription?

Ans. Boric acid, 45.57 grn.; Carbolic acid, 36.45 grn.

5.—Make one fluidounce of a 2-per cent. veratrine oleate.

When the solvent does not have the same specific gravity as water, then the specific gravity of the solvent must be considered. A fluidounce of water weighs 455.7 grains; a fluidounce of oleic acid, having a specific gravity of 0.9, weighs $0.9 \times 455.7 = 410.13$ grains: $410.13 \times 0.02 = 8.2$ grains of veratrine to be added to sufficient oleic acid to make 410.13 grains.

Rule.—Reduce the volume to its equivalent weight and multiply by the specific gravity of the solvent and multiply this product by the given per cent.

6.—How many grains of boric acid are required to make 4 fluidounces of a 5-per cent. solution in glycerin, sp. gr. 1.25?

Ans. 113.9 grains of boric acid.

7.—How many grains of iodine are required to make 4 fluid ounces of a 5-per cent. solution in alcohol, sp. gr. 0.82?

8.—How many grammes of iodine must be dissolved in alcohol, specific gravity 0.82, to make 50 cubic centimeters of 5-per cent. solution?

9.—Make half a fluidounce of carbolated oil containing 5 per cent. of carbolic acid.

If the specific gravity of the solvent is unknown, measure the required volume of the solvent and weigh it, then calculate the amount of the substance to be dissolved. Thus: Half a fluidounce of the oil weighs 208 grains: 5 per cent. of 208 grains is 10.4 grains, the amount of carbolic acid to be used: $208 - 10.4 = 197.6$, the number of grains of oil to be used.

In the preceding problems the amount of the medicament is so small that its volume has been considered equal to that of the solvent, but such is not the case. The volume occupied by various substances when dissolved in liquids is so variable that no definite correction can be given unless the specific gravity of the resulting solution is known. If the amount is small the decrease in volume need not be considered, but if more than 5 per cent., an allowance should be made for the decrease in volume, when the quantity ordered is by volume. A closer approximation of the desired volume may be obtained by taking a volume of the solvent equal to the volume of the desired product, according to the following:

31.—TO MAKE A SOLUTION OF A GIVEN STRENGTH WHEN THE QUANTITY OF THE SOLVENT IS GIVEN

1.—*Example.*—How many grammes of potassium iodide must be dissolved in 484 cubic centimeters of water to make a 12-per cent. solution?

The finished solution must contain 12 per cent. of potassium iodide and 88 per cent. of water. Then the 484 grammes of

water must be 88 per cent. of the finished solution and 1 per cent. is $\frac{1}{88}$ of 484, or 5.5 grammes. If 5.5 is 1 per cent., then 12 per cent. is 12 times 5.5, or 66 grammes of potassium iodide to be dissolved in 484 grammes of water.

Rule.—Divide the given quantity by 100 minus the given per cent. Multiply the quotient by the given per cent. The product represents the quantity of the substance to be dissolved in the given quantity of the solvent.

2.—How many grammes of zinc sulphate must be dissolved in 470 grammes of water to make a 6-per cent. solution?

Ans. 30 grammes.

3.—How many grains of boric acid must be dissolved in 4 fluidounces of water to make a 5-per cent. solution?

4.—How many grammes of tannic acid must be dissolved in 320 cubic centimeters of glycerin, sp. gr. 1.25, to make a 20-per cent. solution? What will be the weight of the solution?

5.—How many grains of cocaine must be dissolved in 2 fl. oz. oleic acid, sp. gr. 0.900, to make a 2-per cent. oleate?

Ans. 16.74 grains.

32.—TO REDUCE SOLUTIONS FROM A HIGHER TO A LOWER PERCENTAGE

When per cent. by volume is used, the proportional parts are by volume. When per cent. by weight is used the proportional parts are by weight.

When mixing liquids by volume that contract in volume when mixed, they should be allowed to stand until contraction ceases. Then add a sufficient quantity of the diluent to restore the required volume.

I.—BY VOLUME

1.—*Example.*—Make 48.6-per cent. alcohol by volume from 94-per cent. alcohol by volume.

Let the per cent. to which the strong liquid is to be diluted represent the volume of the strong liquid to be taken. Let the per cent. of the strong liquid represent the volume to which the strong liquid is to be diluted, and we have the following:

Take 48.6 volumes of 94-per cent. alcohol and add enough water to make 94 volumes.

Rule.—To the number of volumes of the strong liquid, represented by the required per cent., add sufficient diluent to make the volume represented by the per cent. of the strong liquid.

II—BY WEIGHT

2.—*Example.*—Make 41-per cent. alcohol, by weight, from 91-per cent. alcohol, by weight.

Let the required per cent. represent the number of weight-parts of the strong liquid to be taken. Let the per cent. of the strong liquid represent the number of weight-parts to which the strong liquid is to be diluted.

Take 41 parts by weight of 91-per cent. alcohol and add sufficient water to make 91 parts, by weight.

Rule.—To the number of parts by weight of the strong liquid, represented by the required per cent., add sufficient of the diluent to make the number of parts by weight represented by the per cent. of the strong liquid.

PROBLEMS

3.—How many volumes of 60-per cent. alcohol are required to make 60 volumes of 40-per cent. alcohol?

Ans. 40 volumes.

4.—How many grammes of 28-per cent. ammonia water must be taken to make 28 grammes of 10-per cent. ammonia water?

Ans. 10 grammes.

5.—How many grammes of strong sulphuric acid are required to make 92.5 grammes of U. S. P. dilute sulphuric acid?

6.—How many cubic centimeters of deodorized alcohol are required to make 95.1 cubic centimeters of U. S. P. dilute alcohol?

In the preceding problems the number of parts may be considered as proportional, and, if a greater or less quantity is desired, the proportional parts may be multiplied or divided by the same number, as the case may require. In the third problem, instead of making 60 volumes, 180 volumes may be made by taking 3 times 40 volumes, or 120 volumes of 60-per cent. alcohol, and adding water to 3 times 60 volumes, or 180 volumes. Thus

15 volumes may be made by taking one-fourth of 40 volumes, or 10 volumes of 60-per cent., and adding water to one-fourth of 60 volumes, or 15 volumes. The preceding is identical in practice with the following:

33.—TO MAKE A GIVEN QUANTITY OF SOLUTION OF A GIVEN STRENGTH, BY DILUTING A STRONG SOLUTION

1.—*Example.*—Make 370 grammes of 10-per cent. sulphuric acid from 92.5 per cent. sulphuric acid.

$370 \times 0.10 = 37$, the quantity of absolute acid required.

$37 \div 0.925 = 40$, the number of grammes of 92.5-per cent. sulphuric acid required.

$370 - 40 = 330$, the number of grammes of water required.

Rule.—Multiply the given quantity by the given or desired per cent., and divide by the per cent. of the stronger solution. The quotient is the amount of the stronger solution required to be diluted to the given quantity.

PROBLEMS

2.—How many grammes of glacial acetic acid are required to make 770 grammes of 36-per cent. acid? Ans. 280 Gm.

3.—How many cubic centimeters of 94-per cent. alcohol must be taken to make 517 cubic centimeters of 50-per cent. alcohol?
Ans. 275 Cc. of 94 per cent.

4.—How many Imperial fluidounces of 94-per cent. alcohol are required to make 23.5 Imperial fluidounces of 40-per cent. alcohol?
Ans. 10 fl. oz. of 94 per cent.

5.—How many avoirdupois ounces of 68-per cent. nitric acid are required to make 17 Av. oz. of 10-per cent. acid?

6.—How many grammes of 32-per cent. hydrochloric acid must be taken to make 192 grammes of 10-per cent. acid?

7.—How many grains of 20-per cent. mercury oleate and oleic acid are required to make one Apothecaries' ounce of 5-per cent. mercury oleate?

8.—How many grammes of 18-per cent. opium and sugar of milk are required to make 126 grammes of 14-per cent. opium?
Ans. 98 Gm. of 18-per cent. opium and 28 Gm. of sugar of milk.

34.—TO REDUCE A GIVEN QUANTITY OF A SUBSTANCE, OF A GIVEN PER CENT., TO A LOWER PER CENT.

1.—*Example*.—Dilute 240 grammes of 92-per cent. sulphuric acid to 12-per cent. acid.

$$240 \times 0.92 = 220.8 \text{ grammes of absolute sulphuric acid.}$$

$$220.8 \div 0.12 = 1840 \text{ grammes of 12-per cent.}$$

$$1840 - 240 = 1600 \text{ grammes of water to be added.}$$

Rule.—Multiply the given quantity by the given per cent. and divide by the required per cent. The quotient represents the quantity to which the liquid must be diluted.

2.—How many cubic centimeters of 48-per cent. alcohol can be made from 500 cubic centimeters of 94-per cent. alcohol?

Ans. 979.166 Cc.

3.—How many avoirdupois ounces of 20-per cent. solution of zinc chloride can be made from 4 avoirdupois ounces of 50-per cent. solution of zinc chloride?

4.—How many drams of 6-per cent. mercury oleate may be made from 12 drams of 20-per cent. mercury oleate?

5.—How many avoirdupois ounces of dilute hydrochloric acid can be made from 4 avoirdupois ounces of U. S. P. hydrochloric acid ?

35.—ALLIGATION APPLIED TO PHARMACY

The application of the principles of alligation to the practice of pharmacy admits of extended use. Alligation, as applied to pharmacy, is the method of ascertaining the quantities of substances of different strengths required to be mixed in order to produce a certain mixture of a given strength.

1.—*Example*.—In what proportion must 12-per cent. and 17-per cent. powdered opium be mixed to produce a 14-per cent. opium?

If one part of a 17-per cent. opium is taken, 3 per cent. is gained. To gain 1 per cent. only $\frac{1}{3}$ of a part of 17-per cent. opium must be taken. If one part of 12-per cent. opium is taken

2 per cent. is lost. To lose 1 per cent. only $\frac{1}{2}$ of one part must be taken. If $\frac{1}{2}$ of one part of 17-per cent. and $\frac{1}{2}$ of one part of 12-per cent. are mixed, the gain and loss will balance and a 14-per cent. will be produced. If we multiply both fractions by the same number we do not change the proportion. Therefore, we may take any number of times $\frac{1}{2}$ and $\frac{1}{2}$ and the strength of the resulting mixture will be the same.

Rule.—Find the quantity, the strength of which is greater than the mean rate, that must be taken to gain one of the same denomination as the mean rate. Find the quantity, the strength of which is less than the mean rate, that must be taken to lose one of the same denomination as the mean rate. Change the fractions, if there are any, to whole numbers. The result is the number of parts of each that must be taken to produce the mean rate.

14	17	$\frac{1}{2} \times 6 = 2,$	2 parts of 17% opium
	12	$\frac{1}{2} + 6 = 3,$	3 parts of 12% opium
	<hr/>		
	Make	5	parts of 14% opium

Observe that the number in the final result, in each case, is the same as the figure of the denominator of the fraction, of the substance with which it is to be mixed. From which we deduce the following:

Rule.—Subtract the required per cent. from the greater per cent. and place the difference opposite the lower per cent. Also subtract the lower per cent. from the required per cent. and place the difference opposite the greater per cent. The figures opposite each are the required result.

Thus:

14	17	2,	2 parts of 17%
	12	3,	3 parts of 12%
	<hr/>		
			5 parts of 14%

PROBLEMS

2.—In what proportion must a 6-per cent. and a 14-per cent. drug be mixed to produce one of 8-per cent.?

Ans. 1 part of 14-per cent. and 3 parts of 6-per cent.

3.—In what proportion must 92-per cent. alcohol and 20-per cent. alcohol be mixed to produce 40-per cent. alcohol?

Ans. 13 parts of 20-per cent., and 5 parts of 92-per cent.

4.—Mix 8-per cent. and 28-per cent. ammonia water to make 10-per cent. ammonia water.

5.—In what proportion must 28-per cent. ammonia water and water be mixed to produce 10-per cent. ammonia water?

When per cent. by weight is used, the proportionate parts are by weight. When per cent. by volume is used the proportionate parts are by volume.

When mixing liquids by measure that contract in volume when mixed, they should be allowed to stand until contraction ceases. Then add sufficient quantity of the diluent to make the required volume.

36.—TO FIND THE AMOUNTS NECESSARY TO MAKE A GIVEN QUANTITY

The preceding results are proportional parts, and any multiple of them may be taken so long as their relative proportions are retained. Therefore, if it is desired to make a given amount, it is only necessary to take as many times the number of parts as their sum is contained times in the required amount.

1.—*Example.*—How many ounces of 12-and 18-per cent. powdered opium are required to make 24 ounces of 14-per cent. opium?

14	18	2	1 part of 18-per cent. opium.
	12	4	2 parts of 12-per cent. opium.
			<hr style="width: 100%; border: 0.5px solid black;"/> 3 parts of 14-per cent. opium. $24 \div 3 = 8$

$8 \times 1 = 8$, or 8 oz. of 18-per cent. opium.

$8 \times 2 = 16$, or 16 oz. of 12-per cent. opium.

Make 24 ounces of 14-per cent. opium.

Rule.—Divide the required amount by the sum of the proportional parts, and multiply each member of the proportion by the quotient.

PROBLEMS

2.—How many grammes of 16-per cent. and 10-per cent. opium must be used to make a kilogramme of 14-per cent. opium?

Ans. 666.666 Gm. of 16-per cent.
333.333 Gm. of 10-per cent.

3.—How many grammes of sugar of milk must be mixed with a 25-per cent. triturate to produce 10 grammes of a 10-per cent. triturate?

Ans. 6 Gm. sugar of milk.

4.—How many fluidounces of water and 28-per cent. ammonia water are required to make one quart of 10-per cent. ammonia water? As the per cent. of ammonia gas is by weight, a correction must be made for the difference in specific gravity.

5.—How many grammes of 1.5 per cent. and 4-per cent. hydrogen peroxide water must be mixed to make 100 grammes of 3-per cent. hydrogen peroxide water?

6.—How many avoirdupois ounces of U. S. P. hydrochloric acid and water must be mixed in order to produce one pint of 10-per cent. hydrochloric acid?

37.—TO FIND THE AMOUNT OF ONE INGREDIENT WHEN THE AMOUNT OF THE OTHER IS GIVEN

1.—*Example*.—How many ounces of sugar of milk must be mixed with 20 ounces of a 12-per cent. triturate to make a 5-per cent. triturate?

$$5 \left| \begin{array}{c} 12 \\ 0 \end{array} \right| \begin{array}{c} 5 \\ 7 \end{array} \parallel 20 \div 5 = 4$$

Seven parts of sugar of milk are required for every 5 parts of triturate, therefore $4 \times 7 = 28$, the number of parts of sugar of milk to be added.

Rule.—Find the proportion in which they are to be mixed. Divide the given quantity by the proportionate part of that quantity. Multiply the remaining proportionate part by the quotient arising from this division.

PROBLEMS

2.—How many avoirdupois ounces of water must be added to 30 avoirdupois ounces of 25-per cent. nitric acid to produce a 5-per cent. nitric acid? Ans. 120 Av. oz.

3.—How many grammes of 20-per cent. alcohol must be added to 1000 grammes of 80-per cent. alcohol to make a 55-per cent. alcohol? Ans. 714.285 Gm.

4.—Given 10 apothecaries' ounces of 91-per cent. alcohol to make a 45.5-per cent. alcohol. How many ounces of 20-per cent. alcohol are required?

5.—Desired to make a solution containing 20 per cent. of hydrochloric acid, using 80 grammes of strong U. S. P. acid, and a sufficient quantity of dilute U. S. P. acid. How many grammes of the latter are required?

6.—How many ounces of 92-per cent. alcohol must be added to 100 ounces of 30-per cent. alcohol to make a 50-per cent. alcohol?

7.—Given 25 ounces of 15-per cent. alcohol to make 45-per cent. alcohol. How many ounces of 85-per cent. alcohol are required?

38.—WHEN MORE THAN TWO SUBSTANCES OF DIFFERENT STRENGTHS ARE TO BE MIXED

1.—*Example.*—In what proportion must 8-, 10-, 16-, and 18-per cent. opium be mixed to form a 14-per cent. opium?

$$14 \left[\begin{array}{l} 8 \frac{1}{4} 2, 2 \text{ parts of } 8\% \text{ opium} \\ 10 \frac{1}{2} 1, 1 \text{ " " } 10\% \text{ " } \\ 16 \frac{1}{4} 2, 2 \text{ " " } 16\% \text{ " } \\ 18 \frac{1}{6} 3, 3 \text{ " " } 18\% \text{ " } \end{array} \right]$$

When an odd number of substances are used, or when the number of weaker per cents. exceed the stronger, or vice versa, some of the terms must be used more than once. Thus:

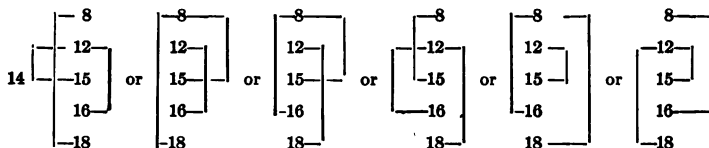
2.—In what proportion must 8-, 16-, and 18-per cent. opium be mixed to form a 14-per cent. opium?

$$14 \left[\begin{array}{l} 8 \\ 16 \\ 18 \end{array} \right] \left[\begin{array}{l} 2 \\ 6 \\ 6 \end{array} \right] \left[\begin{array}{l} 4 \\ 6 \\ 6 \end{array} \right] \left[\begin{array}{l} 1 \\ 1 \\ 1 \end{array} \right] \left[\begin{array}{l} \text{part of } 8\% \text{ opium} \\ \text{" " } 16\% \text{ " } \\ \text{" " } 18\% \text{ " } \end{array} \right] \} = 3 \text{ parts of } 14\% \text{ opium.}$$

Rule.—Write the per cents. in a column. Connect each one of the terms which is less than that of the required term with one that is greater, and each of those that are greater with those that are less. Solve each couplet as before.

When there are several different terms, as many different results may be obtained as different couplets can be formed.

3.—*Example.*—Obtain different results by mixing 18-, 16-, 15-, 12-, and 8-per cent. to form 14-per cent. Thus:



The student may secure as many different results as possible from the following problems.

PROBLEMS

4.—In what proportion, by volume, must 90-, 85-, 80-, 45-, 30-, 25-, and 20-per cent. alcohols be mixed to produce a 40-per cent. alcohol?

5.—Mix 92-, 84-, 16-, and 8-per cent. sulphuric acids, to produce a 48-per cent. acid by weight.

6.—How many grammes of 90-, 60-, 40-, and 10-per cent. sulphuric acids are required to make a 20-per cent. acid by weight?

39.—WHEN THE QUANTITIES OF MORE THAN ONE OF THE TERMS ARE GIVEN

1.—*Example.*—How many grammes of water are required to make a 10-per cent. sulphuric acid from 25 grammes of 30-per cent. and 50 grammes of 60-per cent. sulphuric acid?

If we mix 25 grammes of 30-per cent. with 50 grammes of 60-per cent., we will have 75 grammes of 50-per cent. Thus:

$$\begin{array}{r}
 25 \times 30 = 750 \\
 50 \times 60 = 3000 \\
 \hline
 75 \qquad 3750 \qquad 3750 \div 75 = 50
 \end{array}$$

The question now becomes, how many grammes of water are required to make 10-per cent. sulphuric acid from 75 grammes of 50-per cent. sulphuric acid?

10	50	10	1 part of 50% sulphuric acid.
	0	40	4 parts of water.

If 1 gramme of 50-per cent. sulphuric acid requires 4 grammes of water, 75 grammes will require 75 times 4 grammes, or 300 grammes of water.

Rule.—Multiply each quantity by its per cent. and divide the sum of the products by the sum of the given quantities. The quotient is the mean per cent. Proceed as in 37, using the sum of the given quantities and the mean per cent. as one term.

2.—How many grains of 18-per cent. opium must be mixed with 50 grains of 12-per cent., 80 grains of 13-per cent., and 40 grains of 10-per cent. opiums to make powdered opium containing 14 per cent. morphine? Ans. 85 grains of 18-per cent.

3.—A pharmacist has recovered 200 Cc. of alcohol, having a specific gravity of 0.8526, and 450 Cc. of alcohol having a specific gravity of 0.909. How many Cc. of alcohol, 92-per cent. must be added to make an 88-per cent. alcohol?

Ans. 3124.87 Cc.

Note.—From the alcohol tables of the Pharmacopœia find the per cent. by volume corresponding to the specific gravities, given at 15° C., and proceed as before.

4.—How many grammes of oleic acid must be added to 10 grammes of 20-per cent. and 25 grammes of 15-per cent. oleate of mercury, to make a 5-per cent. oleate of mercury?

5.—How many avoirdupois ounces of carbolic acid, 95-per cent., is it necessary to add to 12 ounces of 5-per cent. and 16 ounces of 12-per cent. to make a solution containing 15 per cent. of carbolic acid?

Alligation may also be expressed in the following form:

14			
8	10	16	18
4	2	4	6
2	1	2	3

Therefore, 2 of 8-per cent., 1 of 10-per cent., 2 of 16-per cent., and 3 of 18-per cent. must be mixed to produce 14-per cent.

40.—ALLIGATION APPLIED TO THE MIXING OF LIQUIDS OF DIFFERENT SPECIFIC GRAVITIES

Alligation may be employed in mixing liquids of different specific gravities, when no change in volume occurs. The process is the same as in articles 35 to 39, except that specific gravities are used in place of per cent. The ratios are by volume.

1.—*Example.*—In what proportion must glycerin, specific gravity 1.25, and water be mixed to produce a specific gravity of 1.10?

$$\begin{array}{r|rr|l} 1.10 & 1.25 & 10 & 2 \text{ parts of glycerin.} \\ & 1.00 & 15 & 3 \text{ parts of water.} \end{array}$$

2.—How many cubic centimeters of hydrochloric acid, specific gravity 1.20, must be mixed with 150 Cc. of hydrochloric acid, specific gravity 1.10, to produce an acid having a specific gravity of 1.16? Ans. 225 Cc.

3.—How many cubic centimeters of water must be added to 84 Cc. of nitric acid, Sp. Gr. 1.42, to make an acid having a Sp. Gr. of 1.075? Ans. 386.4 Cc. of water.

4.—How many fluidounces of alcohol, specific gravity 0.85 and 0.95, must be mixed to make two pints of alcohol having a specific gravity of 0.87?

No dependence can be placed on the results in the case of liquids that contract in volume on being mixed; as the following example will serve to illustrate:

5.—How many cubic centimeters of alcohol, specific gravity 0.812, and water must be mixed to produce 1000 cubic centimeters of alcohol having a specific gravity of 0.93?

$$\begin{array}{r|rr} 0.93 & 0.812 & 7 \\ & 1.000 & 11.8 \end{array}$$

$$1000 \div 18.8 = 53.19$$

$$7 \times 53.19 = 372.33 \text{ Cc. of alcohol.}$$

$$11.8 \times 53.19 = 627.64 \text{ Cc. of water.}$$

$$\hline 999.97$$

According to the above calculation, if 372.33 cubic centimeters of alcohol are mixed with 627.64 cubic centimeters of water, 999.97 cubic centimeters of a mixture having a specific gravity of 0.93 should be produced, but in actual practice it produces 976 cubic centimeters of a mixture having a specific gravity of 0.953.

In order to produce an alcohol having a specific gravity of 0.93, equal volumes of alcohol and water must be mixed. While the difference in specific gravity may appear but slight, the actual difference in strength of the two mixtures amounts to 12.7 per cent. by volume of alcohol.

ATOMIC AND MOLECULAR WEIGHTS

Elements are made up of infinitesimal particles called atoms. There are as many different kinds of atoms as there are elements. An atom is the smallest particle of an element that can enter into the composition of a molecule. A molecule is the smallest particle into which a substance can be divided without losing its identity. Molecules unite to form matter. If matter has weight it follows that molecules and atoms have weight. The relative weights of these atoms, compared with oxygen 16 as a unit, are their atomic weights.

Symbols are used to represent the elements. Each symbol represents one atom of the element, and as each atom has a definite weight, then each symbol must represent a definite weight of the element. As molecules are made up of atoms, it follows that the molecular weight of a substance must be equal to the sum of the weights of the atoms of which it is composed.

41.—TO FIND THE MOLECULAR WEIGHT OF A SUBSTANCE FROM ITS FORMULA

1.—*Example*.—What is the molecular weight of sodium phosphate? One molecule contains $\text{Na}_2\text{HPO}_4 + 12\text{H}_2\text{O}$. The atomic weight of sodium is 23; hydrogen, 1.008; phosphorus, 31.04; oxygen, 16.

2 atoms of Na weigh,	$2 \times 23 = 46.$
25 " " H "	$25 \times 1.008 = 25.2$
1 " " P "	$31.04 = 31.04$
16 " " O "	$16 \times 16 = 256.$
	<hr/>
	358.24 molecular weight.

Rule.—Multiply the atomic weight of each element by the number of atoms of that element in the molecule. The sum of the products will be the molecular weight.

Molecules may contain atoms of like or unlike elements. The molecules of nearly all of the elements contain two atoms; therefore, their molecular weight is twice their atomic weights. The following are the principal exceptions:

Mercury, cadmium, zinc, sodium, and potassium are monatomic; therefore, their molecular weights are the same as their atomic weights. Phosphorus and arsenic are tetratomic; therefore, their molecular weights are four times their atomic weights.

PROBLEMS

Find the molecular weights of the following:

- | | |
|-----------------------------------|-------------|
| 2.—Sodium nitrate | Ans. 85.01 |
| 3.—Water. | Ans. 18.106 |
| 4.—Anhydrous ferrous sulphate. | Ans. 151.91 |
| 5.—Crystallized ferrous sulphate. | |
| 6.—Potassium bromide. | |

Atomic weights are relative weights. Therefore, they may be adapted to the use of any system of weights, or weights of any size. In the sodium phosphate already given, the quantities obtained may be used equally well as grammes, grains, ounces, or pounds. If grains were taken, then 358.24 grains of sodium phosphate would contain 46 grains of sodium, 25.2 grains of hydrogen, 31.04 grains of phosphorus, and 256 grains of oxygen.

42.—TO FIND THE PERCENTAGE COMPOSITION OF A SUBSTANCE WHEN THE MOLECULAR FORMULA IS GIVEN

1.—*Example.*—What is the percentage composition of nitric acid?

The molecular weight of nitric acid is to the atomic weight

of hydrogen as 100 is to the percentage of hydrogen, as shown in the following equation:

$$\begin{array}{l} \text{HNO}_3 : \text{H} :: 100 : x \\ 63.02 : 1.008 :: 100 : 1.599 = \% \text{ of H} \end{array}$$

The molecular weight is to the atomic weight of nitrogen as 100 is to the percentage of nitrogen,

$$\begin{array}{l} \text{HNO}_3 : \text{N} :: 100 : x \\ 63.02 : 14.01 :: 100 : 22.23 = \% \text{ of N} \end{array}$$

As there are three atoms of oxygen in nitric acid, the weight of the combined atoms of oxygen is 48; therefore,

$$\begin{array}{l} \text{HNO}_3 : 3 \text{ of O} :: 100 : x \\ 63.02 : 48 :: 100 : 76.166 = \% \text{ of O} \end{array}$$

Rule.—Multiply the sum of the atomic weights of each element by 100, and divide by the molecular weight of the substance; or, by proportion. The molecular weight is to the sum of the atomic weight of each element as 100 is to x .

PROBLEMS

Find the percentage composition of the following:

2.—Benzoic acid, $\text{HC}_7\text{H}_5\text{O}_2$.

Ans. H, 4.955; C, 68.8; O, 26.21 per cent.

3.—Sodium chloride, NaCl . Ans. Na, 39.34; Cl, 60.65.

4.—Alcohol, $\text{C}_2\text{H}_5\text{O}$. Ans. C, 52.11; H, 13.13; O, 34.73.

5.—Ammonia gas, NH_3 . Ans. N, 82.24; H, 17.75.

6.—Zinc sulphate, ZnSO_4 .

7.—Water, H_2O .

8.—Morphine, $\text{C}_{17}\text{H}_{29}\text{NO}_3$.

9.—Paraldehyde, $\text{C}_6\text{H}_{12}\text{O}_3$.

43.—TO FIND THE PERCENTAGE OF TWO OR MORE ELEMENTS IN A SUBSTANCE WHEN ITS FORMULA IS GIVEN

1.—*Example.*—What per cent. of sulphuric anhydride, SO_3 , and barium oxide, BaO , is present in barium sulphate, BaSO_4 ?

Barium sulphate is to barium oxide as 100 is to the per cent. of barium oxide.

$$\begin{array}{l} \text{BaSO}_4 : \text{BaO} :: 100 : x \\ 233.44 : 153.37 :: 100 : 65.69, \text{ per cent. of BaO.} \end{array}$$

Barium sulphate is to sulphuric anhydride as 100 is to the per cent. of sulphuric anhydride.

$$\begin{array}{l} \text{BaSO}_4 : \text{SO}_3 :: 100 : x \\ 233.44 : 80.07 :: 100 : 34.3, \text{ per cent. of SO}_3. \end{array}$$

Rule.—Multiply the sum of the atomic weights sought by 100, and divide by the molecular weight of the substance given; or by proportion. The molecular weight of the substance given is to the molecular weight of the substance sought as 100 is to the per cent. of the substance sought.

PROBLEMS

2.—What per cent. of water is present in crystallized phosphate of sodium, $\text{Na}_2\text{HPO}_4 + 12 \text{H}_2\text{O}$? Ans. 60.34 per cent.

3.—What per cent. of potassium chloride, KCl , may be obtained from potassium chlorate, KClO_3 , if the oxygen is driven off by heat? Ans. 60.82 per cent.

4.—Ammonia gas forms what per cent. of ammonium chloride?

5.—What per cent. of crystallized sodium carbonate, $\text{Na}_2\text{CO}_3 + 10\text{H}_2\text{O}$, is anhydrous sodium carbonate?

6.—When crystallized ferrous sulphate is heated to 115°C . it loses 6 molecules of water of crystallization. What per cent. is lost?

44.—TO FIND THE WEIGHT OF ONE OR MORE ELEMENTS IN A GIVEN QUANTITY OF SUBSTANCE

1.—*Example.*—How much bromine is there in 12 ounces of potassium bromide?

The molecular weight of potassium bromide is to the atomic weight of the bromine as the given quantity is to the desired quantity.

$$\begin{array}{l} \text{KBr} : \text{Br} :: 12 : x \\ 119.02 : 79.92 :: 12 : 8.05, \text{ ounces of bromine} \end{array}$$

Rule.—The sum of the atomic weights of the substance of which the quantity is given is to the sum of the atomic weights of the substance of which the quantity is desired as the given quantity, is to the weight sought.

PROBLEMS

2.—How many grammes of potassium chloride can be obtained from 1000 grammes of potassium chlorate?

Ans. 608.3 Gm.

3.—How many ounces of exsiccated ferrous sulphate may be manufactured from 25 Av. ounces of crystallized ferrous sulphate, if six molecules of water are removed by heat?

Ans. 15 oz., 106.7 grains.

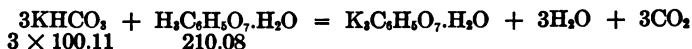
4.—How many lbs. of carbonic acid gas are lost when 50 lbs. of carbonate of lime are converted into oxide?

5.—When crystallized sodium carbonate is exposed to dry air it loses half of its water of crystallization. How many ounces of effloresced sodium carbonate may be obtained from 5 ounces of the crystallized carbonate?

45.—TO FIND THE AMOUNT OF ONE SUBSTANCE REQUIRED TO UNITE WITH A GIVEN QUANTITY OF ANOTHER

When working problems that involve chemical action, it is advisable to first write an equation that completely expresses the chemical action and the exact amount of each substance represented in the equation. This will prevent overlooking cases where more than one molecule of a substance unites with only one molecule of another. In many cases water is in actual combination with a substance, and should not be neglected when it forms a part of one or both terms of a problem, as in the case of citric acid in the problem given below.

1.—*Example.*—How many grains of citric acid are required to unite with 2 drams of potassium bicarbonate to form potassium citrate?



As three molecules of potassium bicarbonate are required to unite with one molecule of citric acid, the number of parts of potassium bicarbonate required to unite with 210.08 parts of citric acid are three times its molecular weight, or 300.33 parts. If 300.33 parts of potassium bicarbonate require 210.08 parts

of citric acid, one part or one grain will require $\frac{1}{300.33}$ of 210.08 or 0.6994 of one grain. Then 120 grains will require 120×0.6994 , or 83.938 grains of citric acid.

Or, by proportion, $300.33 : 210.08 :: 120 : 83.938$ grains of citric acid.

Rule.—Same as under section 44.

PROBLEMS

2.—How many grammes of sodium bicarbonate are required to unite with 600 grammes of absolute sulphuric acid?

Ans. 1027.745 grammes.

3.—If hydrogen sulphide is passed into a solution containing 50 grammes of lead acetate, how many grammes of the gas will be consumed in the precipitation of the lead as sulphide?

Ans. 4.495 Gm.

4.—Find the number of grains of hydrochloric acid gas that will be required to unite with an apothecaries' ounce of potassium bicarbonate.

Ans. 174.86 grains.

5.—Find the number of grains of salicylic acid which must be mixed with 4 drams of sodium bicarbonate to form sodium salicylate.

Ans. 394.381 grains.

6.—Find the number of grammes of ammonium carbonate required to combine with 200 grammes of citric acid to form ammonium citrate.

Ans. 149.677 Gm.

7.—How many grammes of iodine are required to unite with 60 grammes of iron to form ferrous iodide?

8.—How many grammes of iron are consumed in the manufacture of ferrous iodide from 75 grammes of iodine?

9.—How many grammes of potassium iodide are required to unite with 331 grammes of mercuric chloride to form mercuric iodide?

10.—How many grammes of mercury may be dissolved in strong nitric acid, which contains 25 grammes of absolute acid? The solution to be made without heat.

11.—How many grains of absolute hydrochloric acid are required to dissolve 3 drams of mercuric oxide?

46.—TO FIND THE AMOUNT OF SUBSTANCE REQUIRED TO MAKE
A GIVEN QUANTITY OF PRODUCT

1.—*Example*.—How many grammes of silver will be required to make 18 grammes of silver nitrate?

$\text{AgNO}_3 : \text{Ag} :: 18 : x$
169.89 : 107.88 :: 18 : 11.43, the amount of silver required.

Rule.—Same as under section 44.

PROBLEMS

2.—How many ounces of metallic iron, assuming the iron to be pure, will be required to make 32 oz. of crystallized ferrous sulphate?
Ans. 6.437 oz.

3.—How many grains of magnesium oxide will be required to make 450 grains of magnesium sulphate? Ans. 73.6 grains.

4.—How many grammes of pure metallic zinc must be dissolved in hydrochloric acid to make 1500 grammes of zinc chloride?
Ans. 719.31 grammes of Zn.

5.—How many grammes of iodine will be consumed in the manufacture of a kilogramme of lead iodide?

6.—How many grains of bromine are there in an apothecaries' ounce of ferrous bromide?

7.—How many grammes each, of pure calcium oxide and hydrochloric-acid gas, are required to manufacture 500 grammes of crystallized calcium chloride?

47.—TO FIND THE AMOUNT OF MATERIAL FORMED FROM A
GIVEN QUANTITY OF SUBSTANCE

1.—*Example*.—How many grammes of calomel will be formed by treating 100 grammes of corrosive sublimate with an excess of mercury?

PROBLEMS

$\text{HgCl}_2 : 2\text{HgCl} :: 271.52 : 472.12 :: 100 : 173.88 \text{ Gm. of HgCl.}$

Rule.—The same as under section 44.

PROBLEMS

2.—How many grammes of mercuric chloride can be formed from 120 grammes of mercury?

Ans. 162.424 Gm. of HgCl_2 .

3.—How many grains of barium carbonate will be formed by passing carbon dioxide through a solution containing 1000 grains of barium chloride? Ans. 807.83 grn. of BaCO_3 .

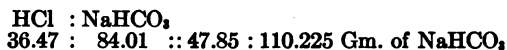
4.—If a solution containing 500 grammes of silver nitrate is precipitated by hydrochloric acid, how much silver chloride will be formed? What quantity of silver does it contain?

5.—If an excess of iron wire is acted upon by 45 grammes of iodine, how many grammes of ferrous iodide will be formed?

48.—WHEN THE GIVEN QUANTITY IS NOT ABSOLUTE BUT OF A DEFINITE STRENGTH

1.—*Example.*—How many grammes of sodium bicarbonate will be required to neutralize 150 grammes of hydrochloric acid?

Absolute hydrochloric acid is a gas, and is found in commerce only as a solution of the gas in water, of varying strength. In the problem the strength of the acid is not given; therefore, it must be considered as the strong pharmacopœial acid, which contains 31.9 per cent. by weight of acid. One hundred and fifty grammes of hydrochloric acid contains 31.9 per cent. of 150, which is 47.85 Gm. of absolute HCl .



Rule.—Multiply the given quantity by the per cent. and proceed as in section 44.

PROBLEMS

2.—How many grains of barium sulphate will be precipitated by treating 4 apothecaries' ounces of dilute sulphuric acid with barium chloride? Ans. 466.7 grains.

3.—How many ounces of pure potassium hydroxide may be neutralized by 100 ounces of 10-per cent. nitric acid?

Ans. 8.9 oz.

4.—How many grammes of magnesium carbonate may be formed from 250 grammes of a 30-per cent. solution of magnesium sulphate?

5.—If an excess of zinc is treated with 12 avoirdupois ounces of hydrochloric acid, how many ounces of zinc chloride will be formed?

6.—If 400 grains of sodium carbonate, which contains 75 per cent. of anhydrous sodium carbonate, be treated with salicylic acid, how many grains of sodium salicylate will be formed?

49.—WHEN THE DESIRED QUANTITY IS TO BE OF A CERTAIN STRENGTH

1.—*Example.*—How many grammes of 10-per cent. hydrochloric acid will be required to precipitate the silver from a solution containing 12 grammes of silver nitrate?

In this case the per cent. does not refer to the substance of which the quantity is given, but to the required substance. The per cent. cannot be taken into consideration until the amount of absolute substance has been obtained. Therefore, in this problem the first step is to find the amount of absolute hydrochloric acid required and then divide by the per cent.

$$\begin{array}{l} \text{AgNO}_3 : \text{HCl} \\ 169.89 : 36.47 :: 12 : 2.576 = \text{absolute HCl} \\ 2.576 \div 0.10 = 25.76 \end{array}$$

Rule.—Find the amount of absolute substance required, as in section 44, and divide by the per cent.

PROBLEMS

2.—How many grammes of 96-per cent. sulphuric acid will be required to precipitate 725 grammes of lead sulphate from a solution of lead acetate?

Ans. 244.302 Gm. of 96-per cent. sulphuric acid.

3.—How many ounces of 25-per cent. nitric acid will be required to neutralize 5 ounces of sodium bicarbonate?

Ans. 15 oz. of 25% HNO_3 .

4.—How many grammes of 15-per cent. solution of silver nitrate are required to precipitate silver iodide from a solution containing 80 grammes of sodium iodide?

Ans. 604.373 Gm. of 15-per cent. AgNO_3 .

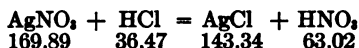
5.—How many grammes of 32-per cent. hydrochloric acid are required to liberate the carbonic acid from 1575 grammes of a 15-per cent. solution of potassium carbonate?

6.—How many ounces of a solution containing 5 per cent. of barium chloride will be required to precipitate twenty-five ounces of a solution containing 20-per cent. of zinc sulphate?

VOLUMETRIC ANALYSIS

50.—VOLUMETRIC SOLUTIONS

Volumetric analysis is the quantitative estimation of substances by means of solutions of known strength, the quantity of substance being determined by the volume of the standard solution used. The strengths of volumetric solutions are based upon their combining power, compared with the valency of hydrogen.



Thus, 36.47 parts of hydrochloric acid will unite with 169.89 parts of silver nitrate. Therefore, if 36.47 grammes of absolute hydrochloric acid are dissolved in a liter of water, and 169.89 grammes of silver nitrate in another liter of water, and the two solutions are mixed, there will be just enough acid to precipitate all the silver. The same will be true if any number of cubic centimeters of one solution be mixed with an equal number of cubic centimeters of the other solution. If one liter of a solution contains 36.47 grammes of hydrochloric acid, each cubic centimeter would contain $\frac{36.47}{1000}$ or 0.03647 gramme, and would be equivalent to 0.16989 gramme of silver nitrate, or, to $\frac{1}{1000}$ of the combining weight, in grammes, of any other substance with which it will unite, *e. g.*, 0.05611 gramme of potassium hydroxide.

A normal solution is one that contains the combining weight, expressed in grammes, of the active reagent in one liter of the solution. The combining weight or valency of a substance must not be confounded with the molecular weight.

The Pharmacopœia defines a normal solution, N/1, as one that contains in 1 liter the molecular weight of the active re-

agent, expressed in grammes, and reduced to the valency corresponding to one atom of replaceable hydrogen or its equivalent.

Hydrochloric acid contains one atom of replaceable hydrogen. Sodium hydroxide and sodium chloride each contain one atom of sodium capable of replacing one atom of hydrogen. Therefore, their normal solutions should contain respectively, HCl, 36.47 Gm.; NaOH, 40.01 Gm.; and NaCl, 58.46 Gm., in one liter. Sulphuric and oxalic acids each contain 2 atoms of replaceable hydrogen. Therefore, one liter of N/1 H_2SO_4 , molecular weight 98.09, should contain 49.045 Gm. One liter of N/1 oxalic acid, $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$, mol. wt. 126.05, should contain 63.025 grammes. Two molecules of potassium permanganate in oxidation give off 5 atoms of oxygen, which are equivalent to 10 atoms of hydrogen; therefore, one-fifth of one molecule of potassium permanganate represents the number of grammes for one liter of normal solution.

$$\frac{\text{KMnO}_4}{158.03} \div 5 = 31.606 \text{ Gm.}$$

Decinormal solutions are one-tenth the strength of normal, and are expressed as N/10. Centinormal solutions are one-hundredth the strength of normal, and expressed as N/100. Seminormal solutions are one-half the strength of normal, and are expressed as N/2. The following strengths are sometimes used: Twice the strength of normal, 2/N. One-twentieth normal, N/20. One-fortieth normal, N/40. One-fiftieth normal, N/50.

The Pharmacopœia gives complete directions for the manufacture of volumetric solutions, and, under each, a list of articles with the amount of each article that is equivalent to one cubic centimeter of the volumetric solution.

51.—TO FIND THE FACTOR

Many volumetric solutions change on standing. When this has occurred, instead of bringing them back to their original strength, many prefer to ascertain their strength and make the necessary correction each time they are used.

1.—*Example*.—On exposure to air a decinormal solution of potassium hydroxide has absorbed carbon dioxide until 10.5 cubic centimeters of the solution are required to neutralize 10

cubic centimeters of decinormal acid. What correction must be made for each cubic centimeter of solution used?

$10 \div 10.5 = 0.952$. If 10.5 cubic centimeters were required instead of 10, then one cubic centimeter of the solution is equal to $\frac{10}{10.5}$, or, 0.952 Cc. Since one cubic centimeter of the solution is the equivalent of only 0.952 of one cubic centimeter of a standard solution, then whenever this solution is used, the number of cubic centimeters of the solution consumed must be multiplied by the factor 0.952.

Rule.—Test the solution with a standard solution and divide the number of cubic centimeters of the standard solution taken by the number of cubic centimeters of the solution used; the quotient will be the factor.

PROBLEMS

2.—What will be the factor of an acid solution if 10 cubic centimeters of a standard alkali solution neutralize 9.4 Cc. of the acid solution? Ans. 1.064.

3.—What is the factor of sodium-thiosulphate solution if 28 Cc. are required to decolorize 25 Cc. of standard iodine solution? Ans. 0.89249.

4.—How many cubic centimeters of standard sulphuric acid are equivalent to 40 Cc. of N/10 acid which has a factor of 1.062? Ans. 42.48 Cc.

5.—How many grammes of silver nitrate in 25 Cc. of N/1 solution having a factor of 0.975?

6.—What is the factor for a solution of potassium hydroxide if 55 Cc. of N/100 are required to neutralize 5 Cc. of a standard N/10 acid?

7.—How many grammes of absolute hydrochloric acid in 45 Cc. of N/20 acid having a factor of 1.02?

8.—What is the factor for a volumetric solution of potassium hydroxide if 22.6 Cc. of N/40 are required to neutralize 5 Cc. of N/10 acid?

52.—ALKALIMETRY

1.—*Example.*—What is the strength of caustic potassa when 0.5 Gm. neutralizes 8 Cc. of N/1 acid?

Since one cubic centimeter of normal acid will neutralize 0.05611 Gm. of potassium hydroxide, 8 cubic centimeters will neutralize 8 times 0.05611 or 0.44888 Gm. If half a gramme of caustic potassa contains 0.44888 gramme of potassium hydroxide, 100 grammes will contain as many times 0.44888 gramme as 0.5 is contained times in 100, or $0.44888 \times \frac{100}{0.5} = 89.776$ Gm., or 89.776 per cent.

Rule.—Find how many cubic centimeters of standard acid are required to neutralize a definite quantity of the alkali, then multiply the number of cubic centimeters of acid used by the equivalent of the alkali that will neutralize one cubic centimeter of acid, and multiply this product by the given quantity divided by the quantity used.

PROBLEMS

2.—How many grammes of potassium hydroxide are there in 800 cubic centimeters of a solution, when 10 cubic centimeters of the solution require 25 cubic centimeters of normal acid to neutralize it?

Ans. 112.22 Gm.

3.—What degree of purity has lithium carbonate if 0.5 gramme of the dry salt, when dissolved in water, neutralizes 13.5 cubic centimeters of normal sulphuric acid, using methyl orange as indicator?

Ans. 99.738 per cent.

4.—How many pounds of anhydrous sodium carbonate are present in 50 lbs. of commercial washing soda, if two grammes, when dissolved in water and titrated, using methyl orange as indicator, require 18 Cc. of N/1 sulphuric acid for neutralization?

Ans. 23.85 lbs.

5.—A pharmacist had 100 pounds of commercial sodium carbonate that had previously lost part of its water of crystallization, so that when tested 1 Gm. neutralized 8 Cc. of N/1 volumetric solution of sulphuric acid. What was its original weight?

6.—How many grammes of ammonia gas in 750 Cc. of ammonia water, if 5 Cc. require 30 Cc. of N/1 sulphuric acid for neutralization?

53.—ACIDIMETRY

1.—*Example.*—How many grammes of absolute hydrochloric acid are there in 160 grammes of acid if 5 grammes of the solution require 40 cubic centimeters of normal potassium hydroxide for neutralization?

Since one cubic centimeter of normal alkali will neutralize 0.03647 gramme of hydrochloric acid, 40 cubic centimeters will neutralize 40 times 0.03647, or 1.4588 grammes of HCl. If 5 grammes of the acid contain 1.4588 grammes, 160 grammes will contain as many times 1.4588 grammes as 5 is contained in 160, or, $1.4588 \times \frac{160}{5} = 46.68$ grammes of absolute hydrochloric acid.

Rule.—Find how many cubic centimeters of standard alkali are required to neutralize a definite quantity of the acid, then multiply the number of cubic centimeters of alkali used by the equivalent of the acid that will neutralize one cubic centimeter of the standard alkali, and multiply this product by the given quantity divided by the quantity used.

PROBLEMS

2.—What is the strength of acetic acid when 30 cubic centimeters of normal potassium hydroxide are required to neutralize 5 grammes of the acid?
Ans. 36 per cent.

3.—When 4 grammes of acetic acid neutralize 40 cubic centimeters of decinormal potassium hydroxide solution, what is the strength of the acid?
Ans. 6 per cent.

4.—How many cubic centimeters of decinormal sulphuric acid are required to neutralize 50 grammes of a 5-per cent. solution of potassium hydroxide?
Ans. 445.57 Cc.

5.—How many grammes of acid in 500 cubic centimeters of commercial hydrochloric acid if 2 cubic centimeters neutralize 17 cubic centimeters of normal potassium-hydroxide solution, factor 0.952?

6.—If 5 grammes of aromatic sulphuric acid are mixed with water and boiled thoroughly, and when cold require 20 cubic centimeters of normal potassium hydroxide for neutralization, what is the strength of the acid?

7.—Forty cubic centimeters of normal potassium hydroxide are required to neutralize 3 grammes of tartaric acid. What is the strength of the acid?

54.—SILVER-NITRATE VOLUMETRIC SOLUTION

PROBLEMS

1.—What per cent. of potassium iodide is present in commercial potassium iodide, when 0.5 Gm. requires 29.8 Cc. of N/10 silver nitrate solution to produce a permanent red color when tested according to the Pharmacopœia?



Ans. 98.947 per cent.

2.—What is the strength of diluted hydrobromic acid, when 1 Gm. requires 12 Cc. of N/10 silver nitrate to produce a permanent red tint with potassium chromate as indicator?

Ans. 9.71 per cent.

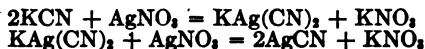
3.—What is the strength of potassium cyanide when 0.5 Gm. of the commercial salt requires 70 Cc. of N/10 silver nitrate solution for complete precipitation?

Ans. 91.15 per cent.

4.—How many grammes of pure potassium cyanide are there in 50 grammes of the commercial salt if 1 gramme requires 69 Cc. of decinormal silver nitrate to produce a faint, permanent precipitate, when tested according to the Pharmacopœia?

Ans. 44.926 Gm.

Note.—As the double cyanide of potassium and silver is formed, one molecule of silver nitrate is equivalent to two molecules of potassium cyanide. Therefore, one cubic centimeter of decinormal silver nitrate is equivalent to 0.01293 Gm. of potassium cyanide. Had the silver solution been added to complete precipitation it would have required 138 Cc., for the double salt would have been broken up and silver cyanide formed as in the third problem. Thus:



5.—What is the strength of dilute hydrocyanic acid if 2 Cc. require 14.2 Cc. of decinormal silver nitrate for complete precipitation?

6.—What per cent. of hydrocyanic acid is present in fl. ext. of wild-cherry bark, when the distillate from 10 Cc. is carried into 10 Cc. of decinormal silver-nitrate solution and 6.5 Cc. of decinormal potassium-sulphocyanide solution are required to precipitate the excess of silver nitrate?

Note.—Volumetric solution of potassium sulphocyanide is only used in residual titration as in above problem. The silver nitrate must be present in excess, and a few drops of a solution of ferric nitrate added, then the excess of silver nitrate determined by adding the solution of sulphocyanide until a permanent reddish-brown tint is produced. Each Cc. of the sulphocyanide is equivalent to one Cc. of the silver nitrate solution.

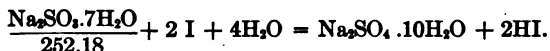
7.—How many grains of ferrous iodide in one avoirdupois pound of syrup of iodide of iron if 1.536 grammes of the syrup, when tested according to the Pharmacopœia, using 6 Cc. of decinormal silver-nitrate solution, require 0.5 Cc. of decinormal sulphocyanide solution to produce a reddish-brown tint? Also, how many grains of syrup must be added to reduce it to the Pharmacopœial strength?

55.—IODINE VOLUMETRIC SOLUTION

PROBLEMS

1.—If one gramme of commercial sodium sulphite be added to 80 Cc. of decinormal iodine solution and 5 Cc. of N/10 sodium thiosulphate solution be required to discharge the color, what per cent. of pure sodium sulphite is present?

Ans. 94.56 per cent.



Note.—As each molecule of sodium sulphite requires two molecules of iodine, each Cc. of decinormal solution of iodine is equivalent to 0.012609 gramme of sodium sulphite.

2.—If 0.1 gramme of arsenic trioxide decolorizes 19.5 Cc. of decinormal iodine solution, what per cent. of pure arsenic trioxide is present?



3.—What per cent. of sulphur dioxide is present in a solution of sulphurous acid, when 2 Gm. diluted with water decolorize 38 Cc. of N/10 iodine solution?

4.—What is the strength of a solution of sodium thiosulphate when 10 Cc. of the solution, containing a few drops of starch paste, require 45 Cc. of N/10 iodine solution to produce a permanent blue color?

5.—How many grammes of arsenic trioxide are present in 1000 Cc. of a solution, if 5 Cc. of the solution are boiled with a mixture of sodium carbonate, a little starch and water to 100 Cc., and when cold require 25 Cc. of N/10 iodine solution to produce a permanent blue color?

56.—SODIUM-THIOSULPHATE VOLUMETRIC SOLUTION

1.—If 0.5 Gm. of iodine requires 39 Cc. of decinormal sodium thiosulphate solution to decolorize the iodine, what is the per cent. of pure iodine? Ans. 98.99 per cent.

2.—How many grammes of iodine are present in 100 Cc. of tincture of iodine, if 6 Cc. require 32 Cc. of N/10 sodium-thiosulphate solution to decolorize it?

3.—If 0.5 gramme of chlorinated lime requires 35.7 Cc. of decinormal sodium-thiosulphate solution to decolorize the iodine liberated from potassium iodide by the chlorine, what is the per cent. of available chlorine?

Note.—This estimation is based on the fact that one atom of free chlorine liberates one atom of iodine from one of its salts.

4.—If twenty-three cubic centimeters of N/10 sodium-thiosulphate solution are required to decolorize the iodine liberated from potassium iodide by 20 grammes of chlorine water, what is the per cent. of free chlorine?

5.—If one gramme of solution of iron tersulphate, when tested according to the Pharmacopœia, requires 14.2 Cc. of decinormal sodium thiosulphate to decolorize the iodine liberated, what is the per cent. of iron in the solution?

Note.—Two atoms of iodine are liberated in the reduction of two atoms of iron from the ferric to the ferrous condition, hence one cubic centimeter of decinormal iodine is equivalent to 0.005584 gramme of iron.

6.—Fifteen cubic centimeters of decinormal sodium thio-sulphate are required to decolorize the iodine liberated when potassium iodide is treated with 0.5 Gm. of iron citrate as directed in the quantitative test for iron citrate. What per cent. of iron is present in the citrate?

57—POTASSIUM-PERMANGANATE VOLUMETRIC SOLUTION

PROBLEMS

1.—If one gramme of commercial ferrous sulphate requires 30 cubic centimeters of potassium-permanganate solution to produce a pink tint, what per cent. of crystallized ferrous sulphate is present?

Ans. 83.28 per cent.

Note.—Ten molecules of ferrous sulphate have been oxidized to ferric by two molecules of potassium permanganate; hence, one-fifth of a molecule of potassium permanganate is equivalent to one molecule of ferrous sulphate.

2.—How many grammes of ferrous carbonate are there in 4 avoirdupois ounces of the saccharated ferrous carbonate, if two grammes require 26 Cc. of decinormal potassium permanganate to produce a pink color:

Note.—The reaction is the same as in the last except that the sulphuric acid first converts the carbonate into a sulphate.

3.—How many grammes of pure potassium hypophosphite are there in 150 Gm. of the commercial salt, if three cubic centimeters of decinormal oxalic acid are required to destroy the pink color left after treating 0.1 Gm. of the salt with 40 Cc. of decinormal potassium permanganate solution?



Note.—As each cubic centimeter of the oxalic-acid solution is equivalent to one cubic centimeter of the potassium-permanganate solution, 37 Cc. of the permanganate solution will be consumed in the oxidation of the hypophosphite.

4.—How many grammes of hydrogen peroxide are there in 200 Cc. of hydrogen-peroxide solution, if 1 Cc. decolorizes 20 Cc. of decinormal permanganate solution?

58—ALKALOIDAL ESTIMATIONS

The volumetric estimation of alkaloids is based upon the fact that they unite with acid to form salts, and thus neutralize a definite amount of acid. The alkaloid is obtained as pure as possible and dissolved in an excess of standard acid, and the excess of acid determined by titration with a standard alkali, using hematoxylin, cochineal, or iodeosin, as indicator. The difference between the standard acid taken and the standard alkali used represents the amount of acid combined with the alkaloid. Most alkaloids that are estimated volumetrically are monobasic; therefore, 1 cubic centimeter of decinormal acid is equivalent to 0.0001 of the molecular weight of the alkaloid expressed in grammes. In case the alkaloid is dibasic the molecular weight should be divided by two and then by 0.0001 to obtain the equivalent of one cubic centimeter of acid.

1.—*Example.*—If the morphine from 2 grammes of opium is dissolved in 12 Cc. of decinormal acid, and 29 Cc. of centinormal alkali are required to neutralize the excess of acid, what is the per cent. of morphine in the opium?

Twenty-nine Cc. of N/100 alkali will neutralize 2.9 Cc. of N/10 acid. Subtracting 2.9 Cc. from the 12 Cc. of acid taken will leave 9.1 Cc. as the amount of acid combined with the morphine. The molecular weight of morphine is 303.18; therefore, 1 Cc. of acid is equivalent to 0.030318 Gm. of morphine, and 9.1 Cc. is equivalent to 0.27589 Gm., the amount from 2 Gm. of opium which, multiplied by 50, will give the per cent., or 13.79 per cent.

PROBLEMS

2.—The morphine from one gramme of opium was dissolved in 5 Cc. of decinormal acid, and required 2 Cc. of centinormal alkali to neutralize the excess of acid; what is the per cent. of morphine in the opium? Ans. 14.55 per cent.

3.—What is the purity of morphine if 0.1 Gm. when dissolved in 5 Cc. of N/10 acid required 7.2 Cc. of N/40 alkali to neutralize the excess of acid? Ans. 97.01 per cent.

4.—What is the per cent. of alkaloid in belladonna root when the alkaloid from 10 Gm. is dissolved in 3 Cc. of N/10 sulphuric acid, and requires 5.5 Cc. of N/50 potassium hydroxide to neutralize the excess of acid? Ans. 0.549 per cent.

Note.—The molecular weights of the alkaloids of belladonna and stramonium are 289.2.

5.—If the alkaloids from 10 grammes of stramonium leaves are dissolved in 2 Cc. of acid, N/10, and 11 Cc. of N/100 alkali are required to neutralize the excess of acid, what is the per cent. of alkaloid?

6.—Ten grammes of coca are macerated in an alkaline mixture containing 100 Cc. of a mixture of chloroform and ether. The alkaloid is removed from 50 Cc. of the chloroform-ether solution and dissolved in 5.5 Cc. of decinormal acid, and it required 44.4 Cc. of centinormal alkali to neutralize the excess of acid. What is the per cent. of cocaine?

7.—The impure morphine from 20 Cc. of tincture of opium weighed 0.28 gramme. One hundred milligrammes of the morphine were dissolved in 5 Cc. of N/10 acid and 6.8 Cc. of N/40 alkali were required to neutralize the excess of acid. How many grammes of morphine are there in 100 Cc. of tincture?

8.—Opium containing 30 per cent. of moisture is dried, and the morphine from 2 grammes of the powder combined with 9.8 Cc. of decinormal acid. What per cent. of morphine did the original moist opium contain?

59.—GASES

Substances existing in the gaseous state are often measured and referred to by volume. Important problems arise as to the volume occupied by a given weight of gas, or the weight of a given volume of gas. Thus it becomes necessary to understand the relation existing between the volume and weight of gases.

The comparative weight of equal volumes of different substances is known as specific gravity. We have seen that, for solids and liquids, water is taken as the unit of comparison. For gases, air or hydrogen serves the same purpose.

The volume of all gases varies under different conditions of temperature and pressure. A gas is said to be normal when the temperature is 0° C., and the atmospheric pressure is 760 millimeters. In all calculations a gas is considered as normal unless otherwise stated.

SPECIFIC GRAVITY OF GASES

60.—TO FIND THE SPECIFIC GRAVITY OF GASES AS COMPARED WITH AIR

1.—*Example*.—One-liter of sulphureted hydrogen weighs 1.52 grammes. What is its specific gravity? The weight of a liter of air is 1.294 Gm. $1.52 \div 1.294 = 1.1746$, the sp. gr.

Rule.—Divide the weight of a volume of the gas by the weight of an equal volume of air.

PROBLEMS

2.—A cylinder holds 142.065 grammes of air and 313.022 grammes of sulphur dioxide. What is the specific gravity of the latter?
Ans. 2.203 sp. gr.

3.—Twelve liters of ammonia gas weigh 9.13 grammes. What is the sp. gr. of the ammonia?

4.—What is the specific gravity of nitrogen, if one liter weighs 1.252 grammes?

5.—What is the specific gravity of chlorine, if two liters of the gas weigh 6.3239 grammes?

61.—TO CHANGE THE SPECIFIC GRAVITY OF GASES FROM AIR AS UNIT TO HYDROGEN AS UNIT

1.—*Example*.—The specific gravity of nitrous-oxide gas as compared with air is 1.52. What is its specific gravity as compared with hydrogen?

Since air is 14.4 heavier than hydrogen, the specific gravity of any gas as compared with hydrogen must be 14.4 greater than the specific gravity when compared with air.

$$1.52 \times 14.4 = 21.888.$$

Rule.—Multiply the specific gravity with air as unit by 14.4, the product will be the specific gravity with hydrogen as unit.

PROBLEMS

The specific gravities of the following gases were obtained with air as unit. What are their specific gravities with hydrogen as unit?
H = 1

2.—Nitric oxide, 1.0344 sp. gr. Ans. 14.895 sp. gr.

3.—Hydrofluoric acid, 0.6905 sp. gr.

4.—Sulphur dioxide, 2.206 sp. gr.

5.—Ozone, 1.6535 sp. gr.

62.—TO CHANGE THE SPECIFIC GRAVITY OF GASES FROM AIR AS UNIT TO OXYGEN AS UNIT

Multiply the specific gravity with air as unit by 0.876. The product will be the specific gravity of the gas compared with oxygen as unit.

If the specific gravities of the following gases are those with air as the unit, what will be their specific gravities with oxygen as unit?

- 1.—Methane, sp. gr., 0.551.
- 2.—Carbon dioxide, sp. gr., 1.515.
- 3.—Ethyl nitrate, sp. gr., 2.585.

63.—TO FIND THE SPECIFIC GRAVITY OF GASES WITH HYDROGEN AS UNIT

One liter of hydrogen weighs 0.08987 gramme and is called a *Crith*.

1.—*Example*.—One liter of oxygen weighs 1.429 Gm. What is its specific gravity?

$$1.429 \div 0.08987 = 15.89 \text{ sp. gr. of oxygen.}$$

Rule.—Divide the weight of a volume of the gas by the weight of an equal volume of hydrogen.

PROBLEMS

2.—What is the specific gravity of ammonia gas, one liter of which weighs 0.7608 gramme? Ans. 8.468 sp. gr.

3.—Ten liters of the vapors of iodine weigh 113.15 grammes. What is its specific gravity?

4.—Five liters of nitrous oxide gas weigh 9.828 grammes. What is its specific gravity?

5.—What is the specific gravity of methane, if four liters weigh 2.858 grammes?

64.—TO CHANGE THE SPECIFIC GRAVITY OF GASES FROM HYDROGEN AS UNIT TO AIR AS UNIT

1.—*Example*.—What is the specific gravity of ammonia gas compared with air? Its specific gravity compared with hydrogen is 8.464. As this is the opposite of section 61, we divide by 14.4 or multiply by its reciprocal, which is 0.0694.

Ans. 0.587 sp. gr.

Rule.—Divide the specific gravity of gases having hydrogen as unit by 14.4 or multiply by 0.0694.

PROBLEMS

The specific gravities of the following gases are given with hydrogen as unit. What are their specific gravities with air as unit?

2.—Arsine, 38.725,

3.—Methane, 7.95.

4.—Carbon dioxide, 21.83.

5.—Ethyl nitrite, 37.245.

Air = 1

Ans. 2.689 sp. gr.

65.—TO CHANGE THE SPECIFIC GRAVITY OF GASES FROM HYDROGEN AS UNIT TO OXYGEN AS UNIT

Divide the specific gravity with hydrogen as unit by 15.88. The quotient will be the specific gravity of the gas compared with oxygen as unit.

Change the following specific gravities with hydrogen as unit to specific gravities with oxygen as unit.

1.—Ammonia gas, sp. gr., 8.465.

2.—Chlorine, sp. gr., 35.18.

3.—Sulphur dioxide, sp. gr., 31.795.

4.—Carbon dioxide, sp. gr., 21.74.

66.—TO FIND THE SPECIFIC GRAVITY OF GASES WITH OXYGEN AS UNIT

Divide the weight of a given volume of the gas by the weight of an equal volume of oxygen, or divide the weight of a liter of the gas by the weight of a liter of oxygen, which is 1.429.

The weight of a liter of nitrogen is 1.247 Gm. What is its specific gravity compared with oxygen?

The weight of three liters of ethyl nitrite gas is 10.04 Gm. What is its specific gravity?

Methane is 7.95 times heavier than hydrogen. What is its specific gravity compared with oxygen?

A liter of nitric oxide weighs 1.349 Gm. What is its specific gravity?

67.—TO CHANGE THE SPECIFIC GRAVITY OF GASES FROM
OXYGEN AS UNIT TO HYDROGEN AS UNIT

Multiply the specific gravity with oxygen as unit by 15.88. The product will be the specific gravity of the gas compared with hydrogen as unit.

The following specific gravities are with oxygen as unit. What will be their specific gravities with hydrogen as unit?

Chlorine, sp. gr., 2.216.

Hydrogen sulphide, sp. gr., 1.062.

Ozone, sp. gr., 1.5.

68.—TO CHANGE THE SPECIFIC GRAVITY OF GASES FROM
OXYGEN AS UNIT TO AIR AS UNIT

Multiply the specific gravity with oxygen as unit by 1.14. The product will be the specific gravity with air as unit.

The specific gravities of the following gases are with oxygen as unit. What will be their specific gravities with air as unit?

Arsine, sp. gr., 2.436.

Phosphine, sp. gr., 1.063.

Hydrochloric acid gas, sp. gr., 1.14.

69.—THE RELATION OF MOLECULAR WEIGHT TO SPECIFIC
GRAVITY AS COMPARED WITH OXYGEN

As all molecules of gases are of the same volume, under like conditions of temperature and pressure, and molecular weights of gases are the relative weights of equal volumes compared with oxygen, it follows that the ratio of the molecular weights of two gases are the same as the ratio of their specific gravities.

Mol. wt.	Mol. wt.	Sp. gr.	Sp. gr.
of CO ₂	: of NO ₂	:: of CO ₂	: of NO ₂
44	: 46.02	:: 1.375	1.438

Therefore the molecular weight of oxygen is to the molecular weight of a gas as 1 is to the specific gravity of the gas. Hence, to find the specific gravity of a gas from its molecular weight, divide its molecular weight by 32. The product will be its specific gravity.

The molecular weight of carbon dioxide is 44, which divided by 32 gives 1.375 as its specific gravity.

PROBLEMS

Find the specific gravities of the following from their molecular weights:

- 2.—Nitrogen.
- 3.—Ammonia gas.
- 4.—Ethyl nitrite.
- 5.—Chlorine.
- 6.—Sulphur dioxide.
- 7.—Nitrous oxide.

70.—TO FIND THE WEIGHT OF A GIVEN VOLUME OF GAS

In the following problems in this work oxygen will be understood as the standard unit unless otherwise stated.

- 1.—*Example*.—What is the weight of 25 liters of chlorine?

One liter of oxygen, 1.429 Gm., multiplied by the sp. gr. of chlorine, 2.216, and by 25 gives 79.16 Gm., as the weight of 25 liters of chlorine.

Rule.—Multiply the weight of one liter of oxygen by the specific gravity of the gas and by the given volume expressed in liters.

PROBLEMS

- 2.—How many grammes in 450 liters of sulphur dioxide?
- 3.—If the specific gravity of bromine vapor is 79.34, what will 75 liters weigh?
- 4.—How many grammes of arsine are required to fill a five-liter flask?
- 5.—How many grammes of nitrous oxide gas are required to fill a 10-gallon cylinder?
- 6.—How many grammes of nitrous oxide gas are required to fill a 25-liter cylinder? Sp. gr. of N_2O is 1.518 when air = 1.

71.—TO FIND THE VOLUME OF A GIVEN WEIGHT OF GAS

- 1.—*Example*.—What is the volume of 79.5 grammes of chlorine?

$$\frac{79.5}{1.429 \times 2.216} = 25.11 \text{ liters.}$$

Rule.—Divide the given weight by 1.429 multiplied by the specific gravity of the gas.

PROBLEMS

2.—How large a flask will be required to hold 30 grammes of sulphur dioxide?

3.—How many liters in 480 grammes of oxygen?

4.—How many liters must a tank contain in order to hold 50 grammes of sulphuretted hydrogen?

5.—How many liters of oxygen can be obtained from 100 grammes of potassium chlorate?

6.—How many liters of carbon dioxide can be liberated from 150 grammes of calcium carbonate?

7.—How many liters of hydrogen will be consumed in the manufacture of reduced iron from 5 grammes of ferric oxide?

72.—TO FIND THE SPECIFIC GRAVITY OF A MIXTURE OF GASES
WHEN THE COMPOSITION AND QUANTITY OF
EACH ARE KNOWN

1.—*Example*.—If two liters of oxygen are mixed with eight liters of nitrogen, what is the specific gravity of the mixture?

From the molecular formula of each we find its specific gravity and then proceed as follows:

$$\begin{array}{r} 1 \times 2 = 2 \\ 0.875 \times 8 = 7 \\ \hline 10 \quad 9 \end{array}$$

$$9 \div 10 = 0.9 \text{ sp. gr. of the mixture.}$$

Rule.—Find the specific gravity of each from its molecular formula; then multiply the specific gravity of each by its volume, add the products and divide by the total volume of the mixture.

PROBLEMS

2.—What is the specific gravity of a mixture containing 2 volumes of carbon dioxide, 3 volumes of oxygen, and 12 volumes of nitrogen?

3.—What is the specific gravity of a mixture of 4 pints of nitrous oxide (N_2O) and one pint of nitric oxide (NO)?

4.—If two liters of nitrous oxide are mixed with 5 liters of air, what will be the specific gravity of the mixture?

5.—One liter of air, 500 cubic centimeters of hydrogen, 250 cubic centimeters of carbon dioxide, and 125 cubic centimeters of arsine are mixed. What is the specific gravity of the mixture?

6.—Four volumes of ammonia gas and three volumes of hydrogen are mixed with two volumes of air. What is the resulting specific gravity?

73.—SPECIFIC VOLUME OF GASES

Specific volume of gases is the relative volume of equal weights of different gases. Specific volume is usually expressed in terms of cubic centimeters, and may be defined as the number of cubic centimeters occupied by one gramme of gas. Hence the specific volume of hydrogen is $\frac{1}{0.00008988} = 11126$ cubic centimeters. The specific volume of air is $\frac{1}{0.001294} = 772.72$ cubic centimeters.

Rule.—Divide one gramme by the weight of one cubic centimeter of the gas, at normal temperature and pressure.

PROBLEMS

What is the specific volume of the following:

- 1.—Hydrochloric acid?
- 2.—Chlorine?
- 3.—Sulphur dioxide?
- 4.—Oxygen?
- 5.—Nitric oxide (NO)?
- 6.—Methane (CH₄)?

74.—GRAMME-MOLECULE

A gramme-molecule is the number of liters occupied by the molecular weight, in grammes, of a gas. The normal volume is 22.39 liters and is the same for all gases under like conditions. The molecular weight of hydrogen is two. Hence, 2 divided by the weight of a liter of hydrogen (0.08987) gives the number of liters occupied by the molecular weight expressed in grammes. The molecular weight of carbon dioxide is 44. Hence 44 grammes of CO₂ will measure 22.39 liters. The molecular weight of chlorine is 70.92, and 70.92 grammes of Cl measure 22.39 liters. The gramme molecule is sometimes used in the calculation of gaseous volumes, but the methods given in sections 70 and 71 are preferred by many.

**75.—TO FIND THE WEIGHT OF A GIVEN VOLUME OF GAS, USING
GRAMME-MOLECULE**

Example.—How many grammes in 25 liters of chlorine?

The number of gramme-molecules may be found by dividing 25 by 22.39, which gives 1.1165; this multiplied by 70.92, the molecular weight of chlorine, gives 79.18218 as the number of grammes in 25 liters.

Rule.—Divide the given volume by 22.39 and multiply by the molecular weight of the gas.

PROBLEMS

Work those given under section 70, using the gramme-molecule.

**76.—TO FIND THE VOLUME OF A GIVEN WEIGHT OF GAS, USING
THE GRAMME-MOLECULE**

How many liters in 212.76 grammes of chlorine?

The weight of a gramme-molecule of chlorine is 70.92 Gm. By dividing 212.76 by 70.92 we have 3 as the number of gramme-molecules in 212.76 Gm. of chlorine. Three times 22.39, or 67.17, liters, is the volume of the chlorine.

Rule.—Divide the given weight by the molecular weight of the gas and multiply by 22.39.

PROBLEMS

Solve those given under section 71, using the gramme-molecule.

VOLUMETRIC COMBINATION AND DECOMPOSITION OF GASES

**77.—TO FIND THE VOLUME OF A GAS THAT WILL UNITE WITH
A GIVEN VOLUME OF ANOTHER GAS**

1.—*Example.*—How many liters of hydrogen will be required to unite with 5 liters of oxygen?

One molecule or one volume of oxygen unites with two molecules or two volumes of hydrogen. Therefore, 5 liters of oxygen will unite with 10 liters of hydrogen.

Rule.—Write the chemical equation to find the number of molecules of each required. Then, the number of molecules of the gas, of which the quantity is given, is to the number of molecules of the gas, of which the volume is required, as the given volume is to the required volume.

PROBLEMS

2.—How many liters of arsine can be produced by combining four liters of hydrogen with arsenic. Ans. 2.666 liters.

3.—If 25 liters of air contain four-fifths nitrogen and it could all be converted into ammonia gas, how many liters would be formed?

4.—How many liters of water vapor will be formed in the manufacture of reduced iron from 15 liters of hydrogen and ferric oxide?

5.—How many liters of hydrogen are required to manufacture a kiloliter of phosphine?

6.—How many pints of hydrogen and oxygen will unite in order to form 5 gallons of vapor of water?

7.—How many pints of oxygen will be consumed by burning sulphur to form a gallon of sulphur dioxide, and how many grains of sulphur will be consumed?

8.—How many liters of hydrogen and chlorine must be united to form 15 liters of hydrochloric acid gas?

78.—THE EFFECT OF TEMPERATURE AND PRESSURE UPON THE VOLUME OF GASES

In many operations gases must be measured at ordinary working temperature and pressure, and, as the volume of a gas varies with each variation of temperature or pressure, a correction must be made for both before we can ascertain its normal volume or its exact weight.

The volume of a gas or vapor is proportional to the pressure it sustains, if the temperature remains the same.

Boyle's Law.—If the pressure is doubled, the volume of the gas will be diminished one-half. If the pressure be diminished one-half, the volume will be doubled. The product obtained by multiplying the volume of the gas by its pressure is always the same regardless of the pressure it sustains. For example, 50 liters of gas are measured at 600 millimeters pressure; 50×600

= 30000. Increase the pressure to 1200 millimeters and the volume is decreased to 25 liters; $25 \times 1200 = 30000$. This being true if the volume and pressure of a gas be given and the pressure be increased or diminished, and either the pressure or volume given, the other may be found.

79.—CORRECTION IN VOLUME OF GASES FOR CHANGE IN PRESSURE

1.—*Example*.—If 30 liters of gas were measured at 400 millimeters pressure and the pressure increased to 800 millimeters, what would be its volume? Thirty multiplied by 400 and divided by 800 gives 15 as the volume of the gas.

Rule.—Multiply the given volume by its pressure and divide by the final pressure.

PROBLEMS

2.—What will be the volume of 25 liters of oxygen at normal pressure, when submitted to 850 millimeters pressure?

Ans. 22.25 liters.

3.—Five volumes of sulphur dioxide are measured at 750 millimeters pressure. What will be its volume at 900 millimeters pressure?

Ans. 4.16 volumes.

4.—One hundred cubic centimeters of nitrous-oxide gas are measured at 780 millimeters pressure. How many cubic centimeters will it occupy at normal pressure?

5.—What will be the weight of 1000 cubic centimeters of oxygen at a pressure of 900 millimeters?

6.—What will be the volume of 10 grammes of sulphur dioxide at a pressure of 500 millimeters?

7.—How many grammes of potassium chlorate will be required to fill a 10-gallon tank with oxygen at a pressure of 735 millimeters?

80.—CORRECTION IN VOLUME OF GASES FOR CHANGES IN TEMPERATURE

All gases expand and contract equally for each degree of change in temperature, the pressure remaining constant.

Charles' Law.—If 273 volumes of gas at 0° C. are heated they increase one volume for each degree. At 10° it will have

increased 10 volumes and have become 283 volumes. The same volume when decreased in temperature from 0°C. to -25°C. will have decreased 25 volumes and have become 248 volumes. If 273 volumes increase or decrease one volume for each degree of change in temperature, then one volume will increase or decrease $\frac{1}{273}$ of its volume for each degree of change in temperature. Expressed decimally this equals 0.003663 of a volume.

1.—*Example.*—If 500 Cc. of gas are measured at 15°C. and then heated to 25°C. What is its volume?

Since 273 volumes, when raised to 15°C. become 288 volumes, and the same volume when raised to 25°C. has become 298 volumes, if 288 volumes have increased to 298 volumes in passing from 15°C. to 25°C. , then one volume will have increased to $\frac{298}{288} = 1.03472$ volumes. If one volume increases to 1.03472 volumes 500 volumes will increase to $500 \times 1.03472 = 517.36$ volumes.

Hence we have $\frac{273+25}{273+15} \times 500 = 517.36$.

Rule.—Divide 273 plus the new temperature by 273 plus the original temperature, and multiply the quotient by the given volume. The product will be the desired volume.

PROBLEMS

2.—If 500 volumes of gas are measured at 0°C. , what will be its volume at 25°C. ? Ans. 545.75 volumes.

3.—Two hundred and fifty cubic centimeters of oxygen are measured at 15°C. and raised to 35°C. ; what will be its volume? Ans. 267.25 Cc.

4.—If 1000 Cc. of gas are measured at 40°C. and the temperature reduced to 10°C. , what will be its volume? Ans. 904.1 Cc.

5.—A gas measures 10 liters at 40°C. , what will be its volume at 0°C. ?

6.—What will be the volume of a gas at -12°C. if it measured 125 volumes at -8°C. ?

7.—What will be the volume of a gas at -15°C. if it measures 250 volumes at 20°C. ?

8.—If one volume of gas is measured at -10°C. what will be its volume at 25°C. ?

81.—CORRECTION IN VOLUME OF GASES FOR CHANGES IN TEMPERATURE AND PRESSURE

1.—*Example.*—If 250 cubic centimeters of oxygen are measured at 10° C. and 760 millimeters pressure, what will be its volume at 30° C. and 775 millimeters pressure?

As we have to correct for both temperature and pressure, we must necessarily combine sections 79 and 80.

$$\frac{250 \times 760 \times (273 + 30)}{775 \times (273 + 10)} = \frac{250 \times 760 \times 303}{775 \times 283} = 262.498 \text{ Cc.}$$

Rule.—Multiply the given volume by its pressure and by 273 plus the new temperature, and divide by the final pressure and by 273 plus the original temperature.

PROBLEMS

2.—What will be the volume of a gas at normal pressure and temperature which measured 750 Cc. at 16° C. and 725 millimeters pressure? Ans. 675.8 Cc.

3.—If spirit of nitrous ether, when tested at 20° C. and 740 millimeters pressure, yields 50 Cc. of nitric oxide gas, how many cubic centimeters of gas would have been produced had the test been made at 25° C. and normal pressure? Ans. 49.45 Cc.

4.—Twenty volumes of carbon dioxide, at normal temperature and pressure, are heated to 200° C. at a pressure of 850 millimeters. What is its volume?

5.—If air is measured at 25° C. and normal pressure, what will be its volume when submitted to a pressure of 1500 millimeters and a temperature of -17° C.?

6.—If 4455 Cc. of vapor are measured at normal pressure and temperature of 27° C., what will be its volume at 15° C. and 745 millimeters pressure?

MENSURATION OF VOLUMES

82.—TO FIND THE VOLUME OF A CYLINDRICAL VESSEL

1.—*Example.*—How many cubic inches in a vessel six inches in diameter and ten inches high?

Since the radius is half the diameter, or 3, the square of the radius is 9, which multiplied by 3.1416 gives the area of the base,

and this multiplied by the altitude, 10, gives the volume of the vessel, or 282.744 cubic inches.

Rule.—Multiply the square of the radius by 3.1416, and that product by the altitude.

PROBLEMS

2.—How many cubic inches in a can five inches in diameter and nine inches high? Ans. 176.71 cu. in.

3.—How many liters in a bottle 160 millimeters in diameter and 3 decimeters high? Ans. 6.03 liters.

4.—How many gallons in a tank 5 feet high and 2 feet 6 inches in diameter? Ans. 183.6 gallons.

5.—How many pounds of mercury will a cylinder hold if its inner measure is 4 inches in diameter and 10 inches high?

6.—How many pounds of glycerin will a can hold that is 18 inches high and 9 inches in diameter?

83.—TO FIND THE VOLUME OF A CONE

1.—*Example.*—What will be the capacity, in cubic centimeters, of a cone whose base is 16 centimeters in diameter and its altitude 30 centimeters?

The area of the base is found, as in section 82, to be 201.0624 square centimeters. If we multiply this by one-third the altitude we have 2010.624 cubic centimeters as the contents of the cone.

Rule.—Multiply the square of the radius by 3.1416 and that product by one-third the altitude.

PROBLEMS

2.—How many cubic centimeters will a funnel hold that is 13.75 centimeters deep and 15 centimeters in diameter?

Ans. 809.94 Cc.

3.—How many cubic inches in a hopper if the top is 16 inches in diameter and the depth 22 inches?

Ans. 1474.4576 cu. in.

4.—How many fluidounces in a cone shaped can, if the diameter of the base is 8 inches and the altitude 15 inches?

Ans. 139.27 fl. oz.

5.—How many fluidounces will a can hold if the diameter is 8 inches and the total height 18 inches, the cone shaped top one-third of the height?

6.—What is the capacity of a can whose diameter is 7 inches and the altitude of the cylinder $8\frac{1}{2}$ inches and that of the cone one and a half inches?

7.—What is the capacity of a folded filter if the diameter of the filter is 25 centimeters?

84.—MISCELLANEOUS PROBLEMS

1.—In what proportion must 25%, 38% and 92% alcohol be mixed to produce 45% alcohol?

2.—How many grains of cocaine hydrochloride will be required to make 2 fluidounces of a 4% solution?

3.—How many grains of mercuric chloride will be required to make a gallon of solution containing 1 to 10,000?

4.—How many fluidounces of glycerin in 10 pounds of solution containing 30% of glycerin?

5.—What is the volume capacity of a can which holds 25 lbs. of ether?

6.—When 100 grains of a substance are placed in a counterpoised bottle and filled with water, the whole weighs 1088 grains. The capacity of the bottle is 1000 grains of water. What is the specific gravity of the substance?

7.—One pound of shot is put into a bottle and filled with water. The total weight is 25,566 grains. The bottle filled with water weighs 19,174 grains. What is the specific gravity of the shot?

8.—A piece of potassium dichromate weighs 120 grammes in air and 64 grammes in alcohol. What is the specific gravity of the potassium dichromate?

9.—What is the specific gravity of a piece of metal which is 3 dm. long, 12.5 cm. wide and 8 cm. thick and weighs 23,400 grammes?

10.—If vanilla costs nine dollars a pound, sugar seven cents a pound and alcohol two dollars and fifty cents a gallon, what will five gallons of tincture of vanilla cost?

11.—What is the strength of a solution of sodium hydroxide which required 15 Cc. of normal sulphuric acid solution to neutralize 12 grammes of the solution?

12.—If silver nitrate is pure, how many grammes of sodium chloride will be required to precipitate all of the silver from 15 grammes of silver nitrate?

13.—How many fluidounces of chloroform will be displaced by two pounds of mercury?

14.—How many grains of sodium bicarbonate will be required to neutralize a fluid ounce of official hydrochloric acid, and how much sodium chloride will be formed?

15.—If ether costs 30 cents a pound and chloroform costs 42 cents, what will be the cost of 2 pints of a mixture having a specific gravity of 1.10, no allowance for contraction?

16.—If ether costs 30 cents a pound and has a specific gravity of 0.716, what will one pint cost?

17.—What will a gallon of glycerin cost at 25 cents a pound?

18.—In what proportion must ether and chloroform be mixed to make a mixture having a specific gravity of 0.876, no allowance for contraction?

19.—How many fluidounces each of ether and chloroform must be mixed to produce one pint of a mixture having a specific gravity of 1.000, no allowance to be made for contraction?

20.—How many grammes of ferrous iodide in 750 Cc. of syrup of ferrous iodide (sp. gr. 1.35) if 4.2% of iodine is used in its manufacture?

21.—If 42 grammes of iodine is used in the manufacture of 1000 grammes of syrup of ferrous iodide, what will be the percentage of ferrous iodide in the syrup?

85.—PROBLEMS BASED ON THE TABLES OF THE PHARMACOPŒIA

Many of the problems of this section may be solved independently. If this is done the answers should be verified by comparison with those obtained from the tables of the Pharmacopœia. The intention is to enable the student to become familiar with these valuable tables.

1.—Reduce 600 Gm. to apothecary ounces and grains.

2.—Reduce 500 Gm. to fluidounces and minims.

3.—How many Gm. in 27 fluidounces and 24.5 minims?

4.—How many avoirdupois ounces in 396.893 grammes?

5.—How many avoirdupois ounces in 200 grammes?

6.—How many milligrammes in 50 grains?

7.—How many grains in 0.972 milligramme?

8.—How many minims in 12 Cc.?

9.—What is the specific volume of a liquid having a specific gravity of 0.920?

10.—What is the volume in liters of a kilogramme of a liquid having a specific gravity of 0.75?

11.—What is the avoirdupois weight of 100 fluidounces of a liquid having a specific gravity of 1.16?

12.—What is the volume in gallons of 100 lbs. of a liquid having a specific gravity of 1.000?

13.—How many fluidounces in 1000 grains of liquid having a specific volume of 0.7576?

14.—How many apothecary ounces in 100 fluidounces of a liquid having a specific volume of 0.5435?

15.—How many fluidounces in 100 avoirdupois ounces of a liquid having a specific gravity of 1.84?

16.—How many fluidounces in 10 lbs. of U. S. P. hydrochloric acid?

17.—How many fluidounces in 8 avoirdupois ounces of U. S. P. chloroform?

18.—If a 50 Gm. pycnometer is standardized at 25° C. and is found to hold 52.165 grains of acetic acid, weighed at 20° C., what will be the per cent. of absolute acetic acid?

19.—If a pycnometer holds 25 grammes of water at 25° C., and 26.5 grammes of acetic acid at 18° C., what will be the percentage strength of the acid?

20.—How many grammes of absolute acetic acid in 600 Cc. of acid having a specific gravity of 1.0350 at 28° C.?

21.—A 100-Cc. pycnometer, which has been standardized at $\frac{15.6^\circ}{15.6^\circ}$ holds at 23° C. 97.1, 93.6, 87.7 and 81.6 grammes of dilute alcohol. From the U. S. P. tables determine the percentage, by volume, of absolute alcohol in each?

22.—What would be the percentage of absolute alcohol in each if the same weights had been obtained at 25° C.?

23.—How many grammes each of sodium bicarbonate and dilute acetic acid will be required to make 5 grammes of sodium acetate?

24.—How many grains each of salicylic acid and monohydrated sodium carbonate will be required to make 5 drams of sodium salicylate?

25.—How many ounces each of sodium bicarbonate and benzoic acid must be taken to make 10 ounces of sodium benzoate?

5.63

841.

26.—In order to make a kilogramme of ammonium citrate how many grammes of ammonium carbonate and citric acid must be taken?

27.—How many grains of potassium carbonate and diluted hydrobromic acid will be required to make 4 ounces of a solution containing a dram of potassium bromide to the ounce?

28.—If a prescription calls for a dram of ammonium benzoate, which is not in stock, from what can it be made and what quantities must be taken?

29.—How many grammes of potassium carbonate will be required to neutralize 25 grammes of lactic acid, and what will be the weight of the potassium lactate formed?

30.—How many grains of ammonium carbonate will unite with 5 scruples of hydrochloric acid and what will be the weight of the product?

31.—What will be the weight, in grains, of benzoic acid necessary to neutralize 2 drams of sodium bicarbonate, and how many grains of sodium benzoate will be formed?

TABLES

The following tables, by Dr. A. B. Lyons, will be found especially valuable for converting the strengths of preparations from one system of weights and measures to those of another. Example: We desire to know the strength, in the metric system, of a preparation that contains 120 grains in a fluidounce. Under grains in a fluidounce, we find 20 and opposite 43.9; also opposite 100 we find 219.5, $43.9 \div 219.5 = 263.4$; the number of grammes in a liter that are equal to 120 grains in a fluidounce.

GRAINS PER FLUIDOUNCE EQUIVALENT TO GRAMMES PER LITER

Grains Per Fluid Oz.	Grammes Per Liter	Grains Per Fluid Oz.	Grammes Per Liter	Grains Per Fluid Oz.	Grammes Per Liter
1	2.2	9	19.8	80	175.6
2	4.4	10	22.0	90	197.5
3	6.6	20	43.9	100	219.5
4	8.8	30	65.9	200	439.0
5	11.0	40	87.8	300	658.5
6	13.2	50	109.8	400	878.0
7	15.4	60	131.7	500	1097.5
8	17.6	70	153.6	600	1316.9

GRAINS PER FLUIDRAM EQUIVALENT TO GRAMMES PER LITER

Grains Per Fluid Dr.	Grammes Per Liter	Grains Per Fluid Dr.	Grammes Per Liter	Grains Per Fluid Dr.	Grammes Per Liter
1	17.6	7	122.9	40	702.4
2	35.1	8	140.5	50	878.0
3	52.7	9	158.0	60	1053.6
4	70.2	10	175.6	70	1229.1
5	87.8	20	351.2	80	1404.7
6	105.4	30	526.8		

**MINIMS PER FLUID OUNCE EQUIVALENT TO CUBIC CENTIMETERS
PER LITER**

Minims Per Fluid Oz.	Cc. Per Liter	Minims Per Fluid Oz.	Cc. Per Liter	Minims Per Fluid Oz.	Cc. Per Liter
1	2.1	9	18.8	80	166.7
2	4.2	10	20.8	90	187.5
3	6.3	20	41.7	100	208.3
4	8.3	30	62.5	200	416.7
5	10.4	40	83.3	300	625.0
6	12.5	50	105.2	400	833.3
7	14.6	60	125.0	480	1000.0
8	16.7	70	145.8		

**MINIMS PER FLUID DRAM EQUIVALENT TO CUBIC CENTIMETERS PER
LITER**

Minims Per Fluid Dr.	Cc. Per Liter	Minims Per Fluid Dr.	Cc. Per Liter	Minims Per Fluid Dr.	Cc. Per Liter
1	16.7	6	100.0	20	333.3
2	33.3	7	116.7	30	500.0
3	50.0	8	133.3	40	666.7
4	66.7	9	150.0	50	833.3
5	83.3	10	166.7	60	1000.0

CUBIC CENTIMETERS PER LITER, EQUIVALENT TO MINIMS, ETC., PER GALLON

Cc. Per Liter	Minims, etc., Per Gallon		Minims, etc. Per Pint		Minims Per Fl. Oz.	Minims Per Fl. Drm.
	Lb. Fl. Oz.	Min.	Fl. Oz.	Min.	Minims	Minims
1	..	61.4	..	7.7	0.5	0.06
2	..	122.9	..	15.4	1.0	0.12
3	..	184.3	..	23.0	1.4	0.18
4	..	245.8	..	30.7	1.9	0.24
5	..	307.2	..	38.4	2.4	0.30
6	..	368.6	..	46.1	2.9	0.36
7	..	430.1	..	53.8	3.4	0.42
8	..	11.5	..	61.4	3.8	0.48
9	..	73.0	..	69.1	4.3	0.54
10	..	134	..	76.8	4.8	0.6
20	..	269	..	153.6	9.6	1.2
30	..	403	..	230.4	14.4	1.8
40	..	58	..	307.2	19.2	2.4
50	..	192	..	384.0	24.0	3.0
60	..	326	..	460.8	28.8	3.6
70	..	461	1	57.6	33.6	4.2
80	..	10 115	1	134.4	38.4	4.8
90	..	11 250	1	211.2	43.2	5.4
100	..	12 384	1	288	48	6
200	1	9 288	3	96	96	12
300	2	6 192	4	384	144	18
400	3	3 96	6	192	192	24
500	4	0 0	8	0	240	30
600	4	12 384	9	288	288	36
700	5	9 288	11	96	336	42
800	6	6 192	12	384	384	48
900	7	3 96	14	192	432	54
1000	8	0 0	16	0	480	60

GRAMMES PER LITER, EQUIVALENT TO GRAINS, ETC., PER GALLON

Grammes Per Liter	Grains, etc., Per Gallon			Grains, etc., Per Pint		Grains Per Fl. Oz.	Grains, Per Fl. Dr.
	Lb.	Oz.	Gr.	Oz.	Gr.	Gr.	Gr.
1	..	..	58.3	..	7.3	0.5	0.06
2	..	..	116.6	..	14.6	0.9	0.11
3	..	..	175.0	..	21.9	1.4	0.17
4	..	..	233.3	..	29.2	1.8	0.23
5	..	..	291.6	..	36.5	2.3	0.29
6	..	..	349.9	..	43.7	2.7	0.34
7	..	..	408.2	..	51.0	3.2	0.40
8	..	1	29.1	..	58.3	3.6	0.46
9	..	1	87.4	..	65.6	4.1	0.51
10	..	1	146	..	72.9	4.6	0.57
20	..	2	291	..	145.8	9.1	1.14
30	..	3	437	..	218.7	13.7	1.71
40	..	5	145	..	291.6	18.2	2.28
50	..	6	291	..	364.5	22.8	2.85
60	..	7	437	..	437.4	27.3	3.42
70	..	9	145	1	72.8	31.9	3.99
80	..	10	291	1	145.7	36.5	4.56
90	..	11	436	1	218.6	41.0	5.13
100	..	13	145	1	292	45.6	5.7
200	1	10	289	3	146	91.1	11.4
300	2	7	434	4	437	136.7	17.1
400	3	5	141	6	291	182.2	22.8
500	4	2	285	8	145	227.8	28.5
600	4	15	430	9	437	273.4	34.2
700	5	13	137	11	290	318.9	39.9
800	6	10	181	13	145	364.5	45.6
900	7	7	426	14	436	410.0	51.3
1000	8	5	133	16	290	455.6	57.0

Tables giving the quantities by weight or measure required to make one gallon of a mixture, each fluidram of which is to contain a given dose. The same table may be used to make one pint by dividing the quantity by eight.

Dose in Grains	Quantity Per Gallon	Dose in Grains	Quantity Per Gallon	Dose in Minims	Quantity per Gallon
	Grains		Lb. Oz. Grains		Pts. Fl. Oz. Min.
1/1000	1.02	0.01	10.24	1/8	128
1/500	2.05	0.02	20.48	1/4	256
1/400	2.56	0.03	30.72	1/3	341.3
1/350	2.93	0.04	40.96	3/8	384
1/333	3.07	0.05	51.20	1/2	1 32
1/320	3.20	0.06	61.44	5/8	1 160
1/300	3.41	0.07	71.68	2/3	1 202.6
1/250	4.10	0.08	81.92	3/4	1 288
1/240	4.27	0.09	92.16	7/8	1 416
1/200	5.12	0.1	102.4	1	2 64
1/160	6.40	0.2	204.8	2	4 128
1/150	6.83	0.3	307.2	3	6 192
1/128	8	0.4	409.6	4	8 256
1/100	10.24	0.5	1 74.5	5	10 320
1/90	11.38	0.6	1 176.9	6	12 384
1/80	12.8	0.7	1 279.3	7	14 448
1/75	13.65	0.8	1 281.7	8	1 1 32
1/70	14.63	0.9	2 46.6	9	1 2 96
1/65	15.75	1	2 149.0	10	1 5 160
1/64	16	2	4 298.0	20	2 10 320
1/60	17.07	3	7 9.5	30	4 0 0
1/55	18.62	4	9 158.5	40	5 5 160
1/50	20.48	5	11 307.5	50	6 10 320
1/48	21.33	6	14 19.0	60	8 0 0
1/45	22.76	7	1 0 168.0	.....	.....
1/40	25.60	8	1 2 317.0	.....	.....
1/35	29.26	9	1 5 128.5	.....	.....
1/32	32	10	1 7 117.5	.....	.....
1/30	34.13	20	2 14 355	.....	.....
1/25	41	30	4 6 95	.....	.....
1/24	42.67	40	5 13 273	.....	.....
1/20	51.2	50	7 5 13	.....	.....
1/18	56.89	60	8 12 190	.....	.....
1/16	64	70	10 3 368	.....	.....
1/15	68.27	80	11 11 109	.....	.....
1/12	85.33	90	13 2 285	.....	.....
1/10	102.4	100	14 10 25	.....	.....
1/8	128	.....	.....	.....	.....
1/6	170.6	.....	.....	.....	.....
1/5	204.8	.....	.....	.....	.....
1/4	256	.....	.....	.....	.....
1/3	341.3	.....	.....	.....	.....
3/8	Oz. 384	.....	.....	.....	.....
1/2	1 74.5	.....	.....	.....	.....
5/8	1 202.5	.....	.....	.....	.....
2/3	1 245.2	.....	.....	.....	.....
3/4	1 330.5	.....	.....	.....	.....
7/8	2 21	.....	.....	.....	.....

International Atomic Weights for 1912

(From "Journal of the American Chemical Society," Vol. XXXIII, page 1642.)

O=16		O=16	
Aluminum.....Al	27.1	Neon.....Ne	20.2
Antimony.....Sb	120.2	Nickel.....Ni	58.68
Argon.....A	39.88	Niton (radium emanation).....Nt	222.4
Arsenic.....As	74.96	Nitrogen.....N	14.01
Barium.....Ba	137.37	Osmium.....Os	190.9
Bismuth.....Bi	208.0	Oxygen.....O	16.00
Boron.....B	11.0	Palladium.....Pd	106.7
Bromine.....Br	79.92	Phosphorus.....P	31.04
Cadmium.....Cd	112.40	Platinum.....Pt	195.2
Cæsium.....Cs	132.81	Potassium.....K	39.10
Calcium.....Ca	40.07	Praseodymium.....Pr	140.6
Carbon.....C	12.00	Radium.....Ra	226.4
Cerium.....Ce	140.25	Rhodium.....Rh	102.9
Chlorine.....Cl	35.46	Rubidium.....Rb	85.45
Chromium.....Cr	52.0	Ruthenium.....Ru	101.7
Cobalt.....Co	58.97	Samarium.....Sa	150.4
Columbium.....Cb	93.5	Scandium.....Sc	44.1
Copper.....Cu	63.57	Selenium.....Se	79.2
Erbium.....Er	167.7	Silicon.....Si	28.3
Fluorine.....F	19.0	Silver.....Ag	107.88
Gadolinium.....Gd	157.3	Sodium.....Na	23.00
Gallium.....Ga	69.9	Strontium.....Sr	87.63
Germanium.....Ge	72.5	Sulfur.....S	32.07
Glucinum.....Gl	9.1	Tantalum.....Ta	181.5
Gold.....Au	197.2	Tellurium.....Te	127.5
Helium.....He	3.99	Terbium.....Tb	159.2
Hydrogen.....H	1.008	Thallium.....Tl	204.0
Indium.....In	114.8	Thorium.....Th	232.4
Iodine.....I	126.92	Thulium.....Tm	168.5
Iridium.....Ir	193.1	Tin.....Sn	119.0
Iron.....Fe	55.84	Titanium.....Ti	48.1
Krypton.....Kr	82.92	Tungsten.....W	184.0
Lanthanum.....La	139.0	Uranium.....U	238.5
Lead.....Pb	207.10	Vanadium.....V	51.0
Lithium.....Li	6.94	Xenon.....Xe	130.2
Lutecium.....Lu	174.0	Ytterbium (Neoytterbium).....Yb	172.0
Magnesium.....Mg	24.32	Yttrium.....Yt	89.0
Manganese.....Mn	54.93	Zinc.....Zn	65.37
Mercury.....Hg	200.6	Zirconium.....Zr	90.6
Molybdenum.....Mo	96.0		
Neodymium.....Nd	144.3		

List of Chemicals used in this Book, together with formula and Molecular Weights.

Acid Acetic.....	$\text{HC}_2\text{H}_3\text{O}_2$	60.03
Acid Benzoic.....	$\text{HC}_7\text{H}_5\text{O}_2$	122.05
Acid Boric.....	H_3BO_3	62.02
Acid Citric.....	$\text{H}_2\text{C}_6\text{H}_5\text{O}_7 \cdot \text{H}_2\text{O}$	210.08
Acid Citric, dry.....	$\text{H}_2\text{C}_6\text{H}_5\text{O}_7$	192.06
Acid Hydriodic.....	HI	127.93
Acid Hydrobromic.....	HBr	80.93
Acid Hydrochloric.....	HCl	36.47
Acid Hydrocyanic.....	HCN	27.02
Acid Nitric.....	HNO_3	63.02
Acid Nitrous.....	HNO_2	47.02
Acid Oxalic.....	$\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$	126.05
Acid Oxalic, dry.....	$\text{H}_2\text{C}_2\text{O}_4$	90.02
Acid Phosphoric.....	H_3PO_4	98.06
Acid Salicylic.....	$\text{HC}_7\text{H}_5\text{O}_3$	138.05
Acid Sulphuric.....	H_2SO_4	98.09
Acid Sulphurous.....	H_2SO_3	82.09
Acid Tartaric.....	$\text{H}_2\text{C}_4\text{H}_4\text{O}_6$	150.05
Alcohol, ethylic.....	$\text{C}_2\text{H}_5\text{OH}$	46.05
Aluminum Hydroxide.....	$\text{Al}(\text{OH})_3$	78.12
Ammonia.....	NH_3	17.034
Ammonium Carbonate (normal).....	$(\text{NH}_4)_2\text{CO}_3$	96.08
Ammonium Carbonate (U. S. P.).....	$\text{NH}_4\text{HCO}_3 \cdot \text{NH}_4\text{NH}_2\text{CO}_3$	157.12
Ammonium Chloride.....	NH_4Cl	53.50
Ammonium Citrate.....	$(\text{NH}_4)_3\text{C}_6\text{H}_5\text{O}_7$	243.17
Arsenic Pentasulphide.....	As_2S_5	310.27
Arsenic Trioxide.....	As_2O_3	197.92
Arsine.....	AsH_3	77.98
Barium Carbonate.....	BaCO_3	197.37
Barium Chloride.....	$\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$	244.32
Barium Chloride, dry.....	BaCl_2	208.29
Barium Sulphate.....	BaSO_4	238.44
Calcium Carbonate.....	CaCO_3	100.07
Calcium Chloride.....	$\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$	219.09
Calcium Chloride, dry.....	CaCl_2	110.99
Calcium Oxide.....	CaO	56.07
Carbon Dioxide.....	CO_2	44.0
Carbon Trioxide.....	CO_3	60.0
Cocaine.....	$\text{C}_{17}\text{H}_{19}\text{NO}$	303.18
Cupric Sulphate.....	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	249.72
Cupric Sulphate, dry.....	CuSO_4	159.64
Ethyl Nitrite.....	$\text{C}_2\text{H}_5\text{NO}$	75.05
Ethyl Oxide (Ether).....	$(\text{C}_2\text{H}_5)_2\text{O}$	74.08
Ferric Chloride.....	$\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	270.32
Ferric Chloride, dry.....	FeCl_3	162.22
Ferric Oxide.....	Fe_2O_3	159.68

Ferric Sulphate.....	$\text{Fe}_2(\text{SO}_4)_3$	399.89
Ferrous Bromide, dry.....	FeBr_2	215.68
Ferrous Bromide.....	$\text{FeBr}_2 \cdot 6\text{H}_2\text{O}$	323.78
Ferrous Carbonate.....	FeCO_3	115.84
Ferrous Iodide.....	FeI_2	309.68
Ferrous Sulphate.....	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	278.02
Ferrous Sulphate, dry.....	FeSO_4	151.91
Hydrogen Dioxide.....	H_2O_2	34.02
Hydrogen Sulphide.....	H_2S	34.09
Lead Acetate.....	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{H}_2\text{O}$	379.20
Lead Acetate, dry.....	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$	325.15
Lead Chloride.....	PbCl_2	278.02
Lead Iodide.....	PbI_2	460.94
Lead Oxide.....	PbO	223.10
Lead Sulphate.....	PbSO_4	303.14
Lead Sulphide.....	PbS	238.17
Lithium Carbonate.....	Li_2CO_3	73.88
Magnesium Carbonate (approx).....	$(\text{MgCO}_3)_4 \cdot \text{Mg}(\text{OH})_2 \cdot 5\text{H}_2\text{O}$	485.70
Magnesium Oxide.....	MgO	40.32
Magnesium Sulphate.....	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	246.50
Magnesium Sulphate, dry.....	MgSO_4	120.39
Mercuric Chloride.....	HgCl_2	271.52
Mercuric Oxide.....	HgO	216.60
Mercurous Chloride.....	Hg_2Cl_2	236.06
Methane.....	CH_4	16.032
Morphine.....	$\text{C}_{17}\text{H}_{19}\text{NO}_5 \cdot \text{H}_2\text{O}$	303.18
Morphine, dry.....	$\text{C}_{17}\text{H}_{19}\text{NO}_5$	285.16
Nitrogen Dioxide.....	NO_2	46.01
Nitric Oxide.....	NO	30.01
Nitrous Oxide.....	N_2O	44.02
Ozone.....	O_3	48.00
Paraldehyde.....	$\text{C}_6\text{H}_{12}\text{O}_3$	132.10
Phosphine.....	PH_3	34.06
Potassium Bicarbonate.....	KHCO_3	100.11
Potassium Bromide.....	KBr	119.02
Potassium Carbonate.....	K_2CO_3	138.20
Potassium Chlorate.....	KClO_3	122.56
Potassium Chloride.....	KCl	74.56
Potassium Citrate.....	$\text{K}_3\text{C}_6\text{H}_5\text{O}_7 \cdot \text{H}_2\text{O}$	324.36
Potassium Citrate, Dry.....	$\text{K}_3\text{C}_6\text{H}_5\text{O}_7$	304.34
Potassium Cyanide.....	KCN	65.11
Potassium Hydroxide.....	KOH	56.11
Potassium Hypophosphite.....	KPH_2O_2	104.16
Potassium Iodide.....	KI	166.02
Potassium Permanganate.....	KMnO_4	158.03
Potassium Phosphate.....	K_2HPO_4	174.25
Potassium Sulphocyanide.....	KSCN	97.18
Silver Chloride.....	AgCl	143.34
Silver Cyanide.....	AgCN	133.89
Silver Iodide.....	AgI	234.80

Silver Nitrate.....	AgNO_3	169.89
Sodium Bicarbonate.....	NaHCO_3	84.01
Sodium Carbonate.....	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$	286.16
Sodium Carbonate, Monohydrated.....	$\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$	124.02
Sodium Carbonate, dry.....	Na_2CO_3	106.00
Sodium Chloride.....	NaCl	58.46
Sodium Hydroxide.....	NaOH	40.01
Sodium Hyposulphite (Thiosulphate).....	$\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$	248.22
Sodium Iodide.....	NaI	149.92
Sodium Nitrate.....	NaNO_3	85.01
Sodium Nitrite.....	NaNO_2	69.01
Sodium Phosphate.....	$\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$	358.24
Sodium Phosphate, dry.....	Na_2HPO_4	142.05
Sodium Salicylate.....	$\text{NaC}_7\text{H}_5\text{O}_3$	160.04
Sodium Sulphate.....	$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$	322.23
Sodium Sulphate, dry.....	Na_2SO_4	142.07
Sodium Sulphite.....	$\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$	252.18
Sodium Sulphite, dry.....	Na_2SO_3	126.07
Sulphur Dioxide.....	SO_2	64.07
Sulphuric Anhydride.....	SO_3	80.07
Water.....	H_2O	18.016
Zinc Chloride.....	ZnCl_2	136.29
Zinc Sulphate.....	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	287.55
Zinc Sulphate, dry.....	ZnSO_4	161.44

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